

FOCUS

**THE HUNT FOR THE
MISSING HALF OF
THE UNIVERSE**

**WHY YOU
DON'T NEED
'FIVE A DAY'**

PLUS MORE MYTHS
UNDER THE MICROSCOPE

HERE COME THE
**NANO
MEDICS**

MEET THE BOTS THAT WILL KILL CANCER,
EAT FAT, REPAIR OUR BODIES AND MORE...

Q&A

What is
the speed
of gravity?

Is there life
in clouds?

Can robots
be creative?



How do we
know how the
brain works?

Why we should
build a colony
on Mercury

The wearables
that will change
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At the heart of the image

WELCOME



At last count there were 2.5 million people in the UK living with cancer. In 2020, it's thought that number will climb to three million (according to Macmillan Cancer Support). The good news is that we're getting better at treating the condition. The trouble is our most commonly used weapons against cancer are effectively a cannon blast to the body. Take, for example, chemotherapy. It targets cells that reproduce rapidly; putting cancerous cells in

its crossfire. But the treatment also kills innocent bystanders like skin and hair cells. What doctors need is a covert operative.

This is where nanomachines could come in. With designs modelled on our body's own defences, microscopic packages could patrol the body incognito and, at the first sign of a cancerous cell, spring open to release a payload that will stunt the cancer cell's growth. It sounds like science fiction, but this treatment is already being trialled with promising results. Find out more about these miniature marvels on p34.

Meanwhile, science fiction author Stephen Baxter makes a compelling case for colonising Mercury on p51. For you stargazers, the planet will pass between the Sun and Earth on 9 May – check out our sister magazine *BBC Sky At Night's* May issue for info on how to observe this rare event.

Finally, one thought has stuck with me while making this month's issue and that's this: the human body generates 53 bathtubs worth of saliva in a lifetime. More facts like these abound in our Q&A on p81.

Daniel Bennett

Daniel Bennett, acting editor

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STUART CLARK

Scientists have been on the hunt for antimatter for nearly a century. But where could we find this intriguing substance and could it change our understanding of physics? Stuart Clark investigates. → p72



ZOE CORMIER

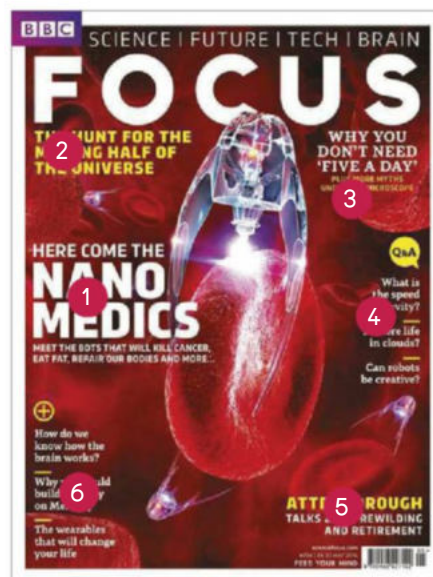
Science writer Zoe Cormier takes a look at new research led by esteemed psychiatrist Prof David Nutt, which has revealed the ways in which LSD can increase connectivity between regions of the brain. → p22



TOM IRELAND

Nanomedicines are a hot topic in the world of science, and could even make us immortal! We asked editor of *The Biologist* Tom Ireland to find out what we can look forward to from these micro machines. → p34

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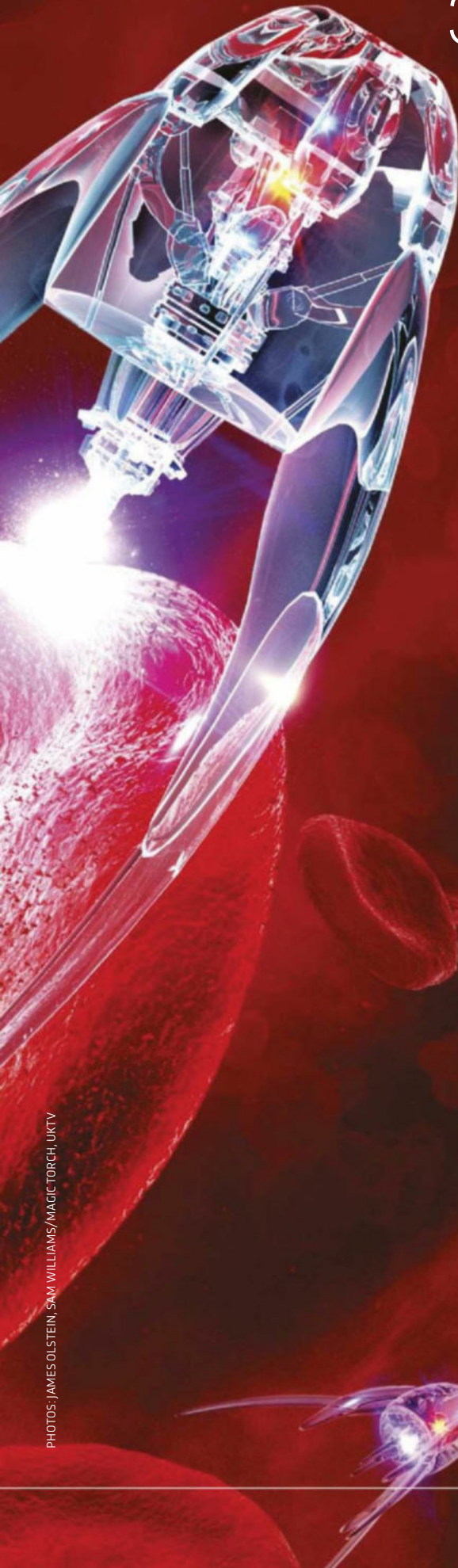
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PHOTOS: JAMES OLSTEIN, SAM WILLIAMS/MAGIC TORCH, UKTV

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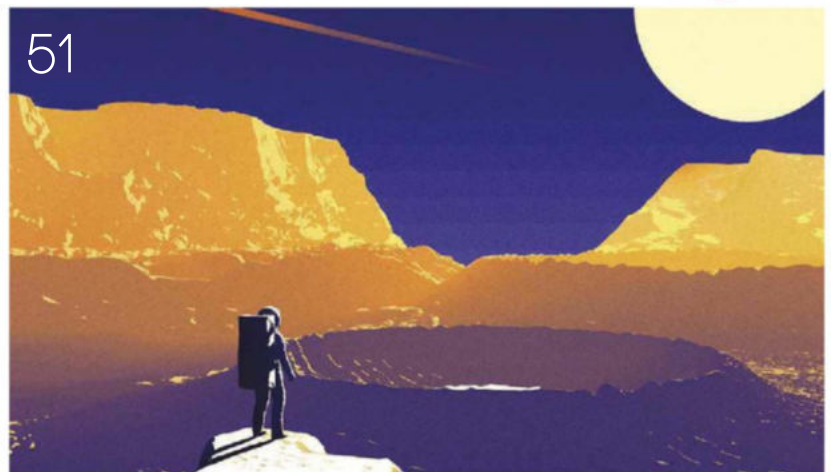
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Disco planet

ISS,
EARTH ORBIT

At night, the Earth becomes a glitterball. Viewed from the International Space Station, lights pulsate and flicker across the planet's surface. Using a long exposure, NASA astronaut Don Pettit captured this light show in June 2012, during a six-month stint aboard the ISS.

The streaks of yellow are city lights, smeared by the rotation of the Earth and the motion of the ISS, while the blue blotches are lightning bolts, flaring up like flashbulbs. That green wash of colour in the atmosphere is known as 'airglow'. It is caused by light being emitted from oxygen atoms that have been excited by the Sun's ultraviolet radiation during the day.

Meanwhile, as the ISS zips around the Earth, the night sky appears to rotate around the space station's axis, creating the star trails in the top-right.

"My star trail images are made by taking a time exposure of about 10 to 15 minutes," says Pettit. "With modern digital cameras, 30 seconds is about the longest exposure possible, [so] to achieve the longer exposures I do what many amateur astronomers do. I take multiple 30-second exposures, then 'stack' them using imaging software."

PHOTO: NASA

NEW MOON RISING

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MESSAGE OF THE MONTH

Crash course

Many years ago I heard a story attributed to Sir Stirling Moss in his heyday. While driving a domestic car in the UK, he was approaching cars stopped at traffic lights when the nearest in front of him decided to reverse. He accelerated up to the car to reduce the time it had to gain speed, stopped just away from its back bumper, allowed it to make contact as he set off in reverse (thus minimising impact), then used his own brakes to slow down and stop the little caravan of vehicles. The story might be apocryphal but I like to think it's true – but only because of the skill of such a driver.

However, a driverless car would be able to do things like this as a matter of course, and thus give another dimension to accident avoidance not normally found. I think that the sheer amount of data available to such cars is going to be so great that they will be capable of accident avoidance measures vastly superior to those of even today's best drivers.

Here's a simple one, based on the philosophy behind supermarket trolleys. They can all go sideways; a future driverless car will be able to do so as well, so that linear space will not be the paramount requirement that it is today. Imagine a driverless car that was stopped in a traffic stream and threatened by a vehicle coming the other way: it would simply step off to the side, something modern cars can't do.

What's more, this could be engineered tomorrow. Just imagine what will be possible in another 100 years or so!

Roger Britton

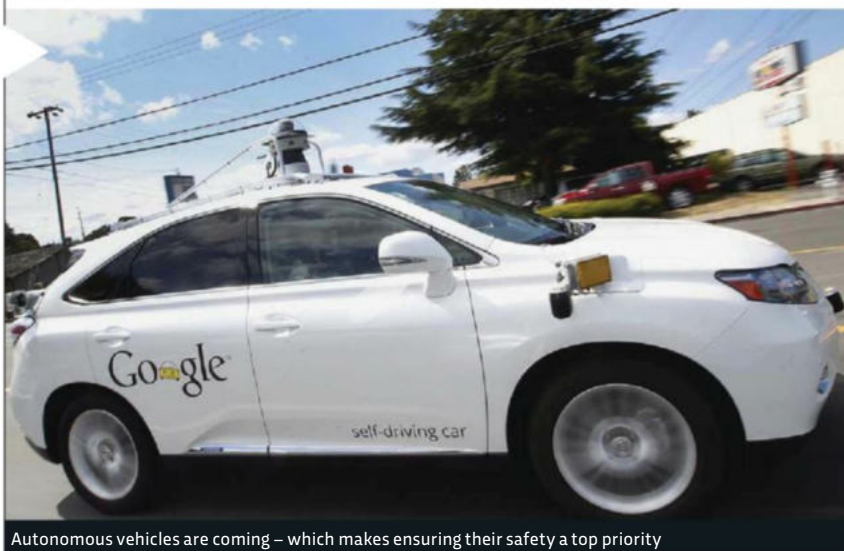
The dawn of the autonomous vehicle does indeed have the potential to reduce road traffic accidents greatly: the tricky bit is ensuring that their AI systems make the 'right' decisions.

– Ed

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **pair of Momentum In-Ears**, worth £89.99. These earphones are made of stainless steel, with no plastics used, to get the best sound out of a small package.

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Autonomous vehicles are coming – which makes ensuring their safety a top priority

Death wish

While reading the article 'Could your driverless car choose to kill you?' (March, p72), I thought about what happens with human drivers. In a crash, there is usually someone at fault, who causes the accident. The whole point of driverless cars would be that the AI would not be at fault. Therefore, there should be no chance of a fatality unless someone else has acted unpredictably and irresponsibly.

If accidents can be safely avoided, great. But if not, I doubt I'd see the moral argument for being shoved into an oncoming

truck because a pair of idiot pedestrians with a death wish didn't stop to look and listen.

Alex Fothergill

Shed light

I've enjoyed reading your magazine for many years; especially enjoying the astronomy and space exploration articles. So I am hoping that you might be able to clear something up for me.

On page 76 of the January 2016 issue, it says that "the Sun seen from Pluto is about 264 times brighter than the full Moon", which is akin to civil twilight on Earth. But then



Hopefully, self-driving cars won't end up in this situation

on page 21 of the March 2016 issue it says that “the light which illuminates Pluto’s landscape is almost zero”, which makes me think of something much darker than twilight.

So I was wondering which statement is correct? Or is it just a matter of context – taking photographs of Pluto from a nearby space probe against trying to photograph it using an Earth-based telescope?

Dave Manton

➔ Somewhat confusingly, both answers are correct. It’s simply that, while the Sun does have considerable brightness as seen from Pluto, its sheer distance from the planet means that all the brightness will appear crammed into a small dot, making it a very poor source of illumination.

To visualise this, think of a laser-pointer. It, too, has a lot of brightness crammed into a tiny spot, but as a torch it’s pretty hopeless!

– Robert Matthews, BBC Focus science consultant

Signal failure

Your recent article ‘One giant leap for GPS’ (April, p27) got me thinking. All these new satellite systems being launched (Galileo, Compass, etc) still don’t address the daily issue we have with ‘no satellite signal’, be that in a tunnel or in a city with high rises, or even inside a building.

How will that ‘health care robot’ navigate without a GPS signal in a 10-storey hospital? How will an order-picking robot benefit in a concrete warehouse? How will that Google car operate in Manhattan, or the Hindhead Tunnel in Surrey when it has little or no GPS signal?

Alex Bruce, Surrey

➔ Any hospital or warehouse that wants to use a GPS robotic system will first need to have its signal strength tested. But buildings that have numerous windows and doors are usually fine. – Ed

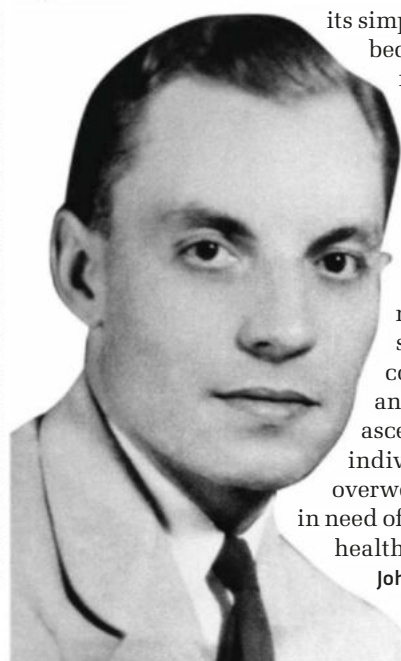
The BMI game

I was interested to read Robert Matthews’ pertinent comments on the Body Mass Index (BMI) in *Focus* (April, p67). It isn’t only muscular



GPS-guided robots are useless if they can’t get a signal

American nutritionist Ancel Keys helped to popularise the concept of the Body Mass Index



athletes who can have an uncharacteristically high BMI compared to their actual body fat levels, but also taller people. Many taller individuals tend to have narrower frames in proportion to their height.

BMI was advocated by Ancel Keys as being appropriate for population studies but inappropriate for individual diagnosis.

Unfortunately, probably due to its simplicity, it has become widely used for individual diagnosis as well.

With obesity and Type 2 diabetes both increasingly posing major health threats in many countries, surely the time has come for an accurate and practical way to ascertain if an individual is indeed overweight and therefore in need of adopting a healthier lifestyle?

John Furniss, Cheltenham

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

MAY 2016

EDITED BY JASON GOODYER

BIOENGINEERING

MEET SYN3.0, THE SIMPLEST LIVING THING ON EARTH

Biologists create synthetic bacteria to help uncover the basic recipe for life

Syn3.0 could become the blueprint for synthetic organisms in the future

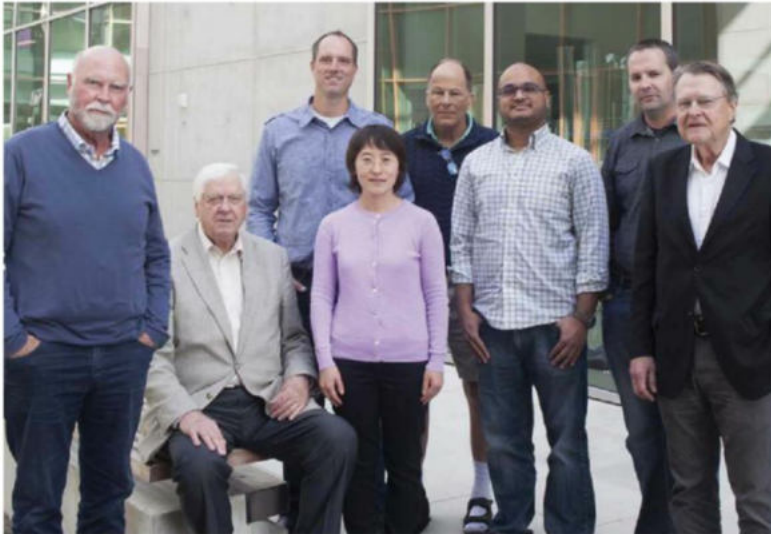
A team led by genomics pioneer J Craig Venter has synthesised a living bacterium that contains all the necessities for life yet has just 473 genes, making it simpler than any self-replicating cell found in nature. Humans have around 24,000 genes.

The researchers hope that the cell will help them to tease out the most basic building blocks of life and begin unravelling the mystery of how complex organisms evolved on Earth, more than three billion years ago. The technique used to create Syn3.0 could also pave the way for the creation of tailor-made organisms that could be used to create new medicines, biofuels or microbes capable of soaking up pollution, the researchers say.

PHOTO: TOM DEERINCK/MARKELLISMAN/UNIVERSITY OF CALIFORNIA AT SAN DIEGO

CRAIG VENTER TIMELINE

BELOW: Craig Venter and the JCVI team that created Syn3.0



Most of Syn3.0's essential genes perform functions related to expressing genes, passing down genetic information, or regulating the cell's membrane and metabolism. However, the team has no idea what around one-third of the cell's genes do.

"Our attempt to design and create a new species, while ultimately successful, revealed that 32 per cent of the genes essential for life in this cell are of unknown function, and showed that many are highly conserved in numerous species," said Venter. "All the bioinformatics studies over the past 20 years have underestimated the number of essential genes by focusing only on the known world. This is an

important observation that we are carrying forward into the study of the human genome."

SIX YEARS IN THE MAKING

Venter and his team first made a synthetic cell with 901 genes, dubbed Synthia or Syn1.0, in 2010 by copying the genome of *Mycoplasma mycoides*, an existing bacteria, and transplanting it into another cell. Taking the success of Syn1.0 as a starting point, the team spent the next six years painstakingly cutting away genes until they were left with a cell with only the genes essential for life.

The results were published in a paper titled 'Design and synthesis of a minimal bacterial genome' in the journal *Science* in March.

"This paper signifies a major step toward our ability to design and build synthetic organisms from the bottom up with predictable outcomes. The tools and knowledge gained from this work will be essential to producing next-generation production platforms for a wide range of disciplines," said the paper's co-author, Daniel Gibson.

"THE TEAM HAVE NO IDEA WHAT AROUND ONE-THIRD OF THE CELL'S GENES DO"

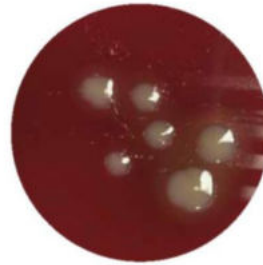
PHOTOS: J CRAIG VENTER INSTITUTE X3, GETTY X2 TOM DEERING/MARK ELLISMAN/UNIVERSITY OF CALIFORNIA AT SAN DIEGO

1946

J Craig Venter is born in Salt Lake City, Utah

1975

Venter graduates from the University of California with a doctorate in physiology and pharmacology



1995

In collaboration with Hamilton Smith, Venter determines the genomic sequence of the *Haemophilus influenza* bacterium, marking the first time the complete genetic sequence of a free-living organism is decoded

2001

The Institute for Genomic Research, founded by Venter, helps sequence the genome of the anthrax strain mailed in the attacks that killed five people — evidence that eventually leads the FBI to the source



2003

The Human Genome Project, led by Venter, decodes the human genome for the first time



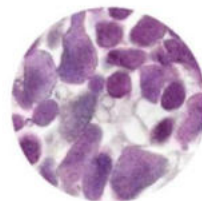
2004

Venter embarks on a two-year trip around the globe by sailboat, in search of microbes for DNA sequencing



2008

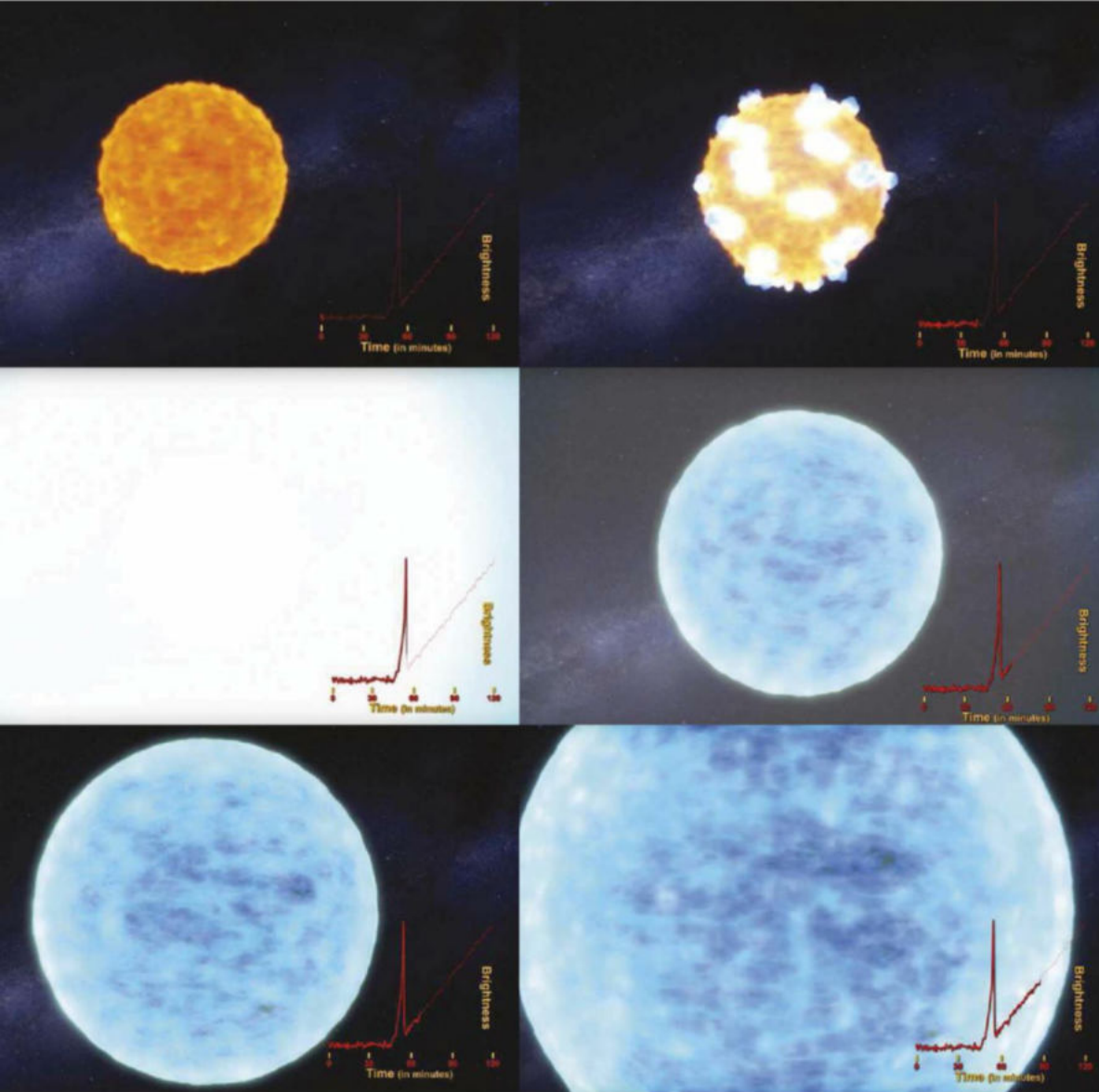
The J Craig Venter Institute (JCVI) announces the complete synthesis of a bacterial genome named *Mycoplasma genitalium*



2010

The JCVI creates Synthia, the first-ever artificial self-replicating organism





SPACE

Exploding star shockwave captured for the first time

When some stars die, they go out with a bang. When the internal furnace of a star many times more massive than the Sun runs out, the force of gravity can take over causing the core to suddenly collapse. This results in the release of enormous amounts of energy in a massive supernova explosion. It can also trigger a gigantic shockwave called a 'shock breakout'.

Now, this shockwave has been captured for the first time in visible light by NASA's Kepler telescope. An international team led by the University of Notre Dame's Peter Garnavich observed the supernova KSN 2011d, a massive star more than 500 times the mass of the Sun, as it exploded 1.2 billion light-years away from Earth. The event was found among three years of observational data and only lasted for around 20 minutes.

"In order to see something that happens on timescales of minutes, like a shock breakout, you want to have a camera continuously monitoring the sky," said Garnavich. "You don't know when a supernova is going to go off, and Kepler's vigilance allowed us to be a witness as the explosion began."

As well as teaching us more about the life cycles of stars, studying these violent events could help us to understand how complex chemicals and even life itself came to be, the researchers said.

Computer-generated
timelapse of the
supernova explosion

THE DOWNLOAD

Elasmotherium sibiricum

What's that? Something to keep your trousers up?
Nope. It's the Siberian Unicorn.

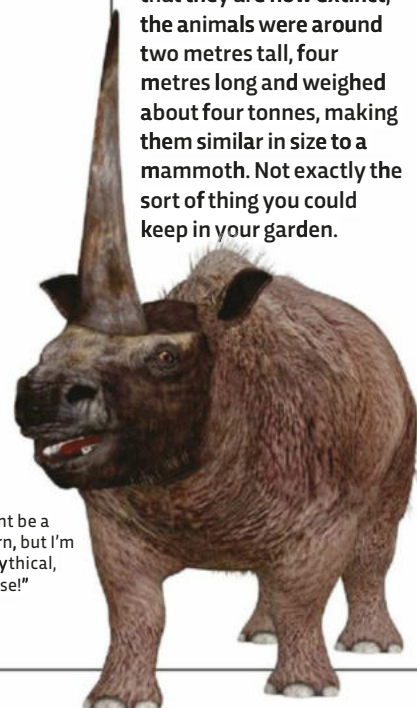
Pull the other one. April Fool's Day was ages ago.

No, really. It was a large, shaggy mammal with a pointy horn sitting on the front of its snout. It was previously believed to have died out 350,000 years ago but a skull recently found in Kazakhstan dates to just 29,000 years ago.

I want one!

Erm, I don't think you do. Quite apart from the fact that they are now extinct, the animals were around two metres tall, four metres long and weighed about four tonnes, making them similar in size to a mammoth. Not exactly the sort of thing you could keep in your garden.

"I might be a unicorn, but I'm not mythical, promise!"



PHOTOS: NASA, ALAMY

TECHNOLOGY

THE 'NEW' OLD MASTER

A new Rembrandt masterpiece has been created by a computer – and it looks just like the real thing

From the earthy colours and theatrical play of light and shadow to the thick layering of paint, all signs point to this portrait being painted by the Dutch master Rembrandt.

However, it was actually created by a computer following a two-year collaboration between the Technical University of Delft, Microsoft and the Mauritshuis and Rembrandthuis museums. The project has been dubbed 'The Next Rembrandt'.

The portrait was created using data from high-res 3D scans of 346 of Rembrandt's portraits.

"There's a lot of Rembrandt data available," said the Technical University of Delft's Joris Dik. "But can we actually create something out of it that looks like Rembrandt? That was an appealing question."

The chosen works were all painted between 1632 and 1642 and featured Caucasian males aged between 30 and 40 wearing black clothes and sporting facial hair in order to limit the number of variables.

The data from the scans was fed into facial recognition software to identify the most typical geometric patterns

Rembrandt used to paint human features. A deep learning algorithm was then used to assemble these findings into an original portrait.

"We looked at a number of Rembrandt paintings, and we scanned their surface texture, their elemental composition, and what kinds of pigments were used," said Dik.

To add a layer of detail, the team used the 3D scans to analyse the texture of Rembrandt's brushstrokes and 3D printed the final portrait using 13 layers of ink to create a realistic effect.

IN NUMBERS

14.53
million km²

The size of the Arctic ice cap recorded by NASA's National Snow and Ice Data Centre. It's the lowest since records began in 1979.

184

The age of Jonathan, a Seychelles giant tortoise living on the island of St Helena in the southern Atlantic Ocean. He's thought to be the oldest living terrestrial animal on the planet.

10
trillion
degrees

That's one followed by 13 zeroes. The temperature of quasar 3C 273, a mysterious disc of matter swirling around a supermassive black hole in the Virgo constellation.

A height map allowed the team to add texture and brushstrokes to the 3D-printed Rembrandt



MEDICINE

STRUCTURE OF THE ZIKA VIRUS MAPPED

This knobbly disc is the first ever image of the structure of the Zika virus, and has potentially paved the way for the development of a vaccine to combat the disease.

WHAT WE LEARNED THIS MONTH

WE COULD BUILD A BASE ON THE MOON BY 2022

NASA scientists have suggested that a base capable of housing 10 astronauts could be built on the Moon using existing technologies in the next five to 10 years. It would cost \$10bn, which is around half of the space agency's yearly budget, they say.

MANTA RAYS CAN RECOGNISE THEMSELVES IN THE MIRROR

Giant manta rays have joined great apes, dolphins and elephants in passing the 'mirror test'. A study in Florida found that rays presented with mirrors wiggled their fins and blew bubbles, suggesting that they were able to recognise their own reflections.

BEING IN SPACE CAN STUNT HAIR GROWTH

Researchers in Tokyo have found that being in orbit can turn on genes that decrease hair growth in men. They found the effect after analysing hair follicles from astronauts who spent six months aboard the International Space Station. The effect was not seen in women.

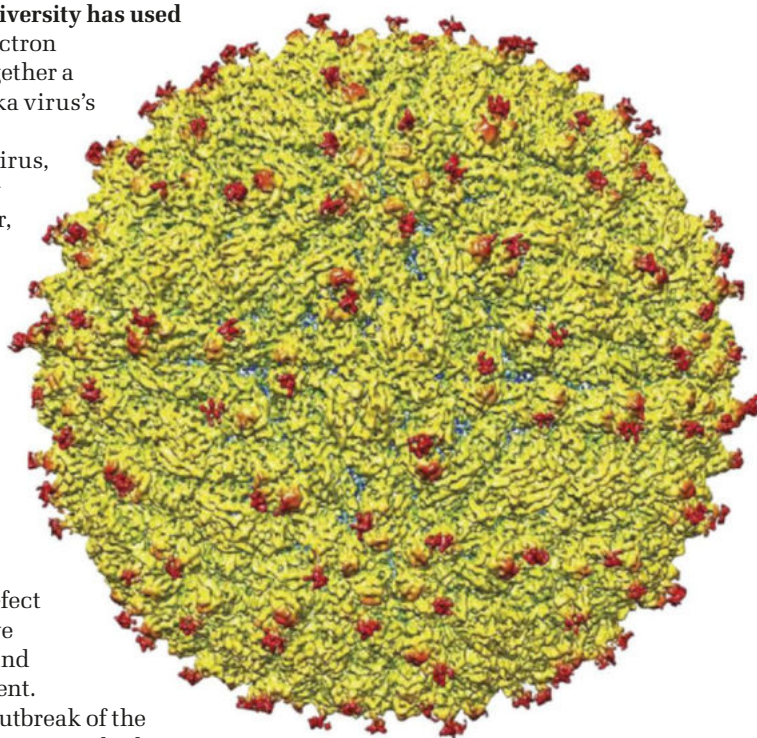
A team from Purdue University has used high-resolution cryo-electron microscopes to piece together a detailed image of the Zika virus's molecular structure.

Zika is a type of flavivirus, a close relative of yellow fever and West Nile fever, which is spread by a species of tropical mosquito. Those infected typically experience mild symptoms such as skin rashes and joint pain that clear up within 10 days. However, growing evidence suggests that the virus maybe linked with microcephaly, a birth defect that causes babies to have unusually small heads and stunted brain development.

In April last year, an outbreak of the virus began in northeastern Brazil. The virus has since spread to other areas of Central and South America, and to the Caribbean.

"The structure of the virus provides a map that shows potential regions of the virus that could be targeted by a therapeutic treatment, used to create an effective vaccine or to

improve our ability to diagnose and distinguish Zika infection from that of other related viruses," said researcher Richard Kuhn. "Determining the structure greatly advances our understanding of Zika, a virus about which very little is known. It shows the most promising areas for further testing and research to combat infection."



"ZIKA IS A VIRUS ABOUT WHICH VERY LITTLE IS KNOWN"

ZIKA FACT BOX



Only one in five people infected with the virus show any symptoms.



First identified in Uganda in 1947.



The virus is spread through the bite of the *Aedes* mosquito, the same insect that transmits yellow fever, dengue fever and chikungunya.



Symptoms include fever, headache, skin rash, red eyes, fatigue and joint pain.

ZOOLOGY

WALKING FISH COULD BE MISSING LINK IN FIN TO LIMB EVOLUTION

Usually, if you drop a fish on the ground it will thrash around aimlessly like, er, a fish out of water. But that's not the case with *Cryptotora thamicola*. Drop one of these blind, cave-dwelling fish on the ground and marvel as it walks away like a land animal.

The bizarre fish was found scurrying around dark caves in Thailand by a team from the New Jersey Institute of Technology. It can scuttle across rocks and climb up waterfalls thanks to its salamander-style pelvic girdle, they say. Other fish, such as mudskippers and lungfish, have previously been observed walking, but those species drag themselves along on their front fins.

The discovery may help to shed light on how the anatomy needed to walk on land evolved after the transition from finned to limbed appendages in the Devonian period, some 420 million years ago.

"*C. thamicola* possesses morphological features that have previously only been attributed to tetrapods [four-legged animals]," said researcher Brooke Flammang. "Its pelvis and vertebral column allow it to support its body weight against gravity and provide large sites for muscle attachment for walking. This research gives us insight into the plasticity of the fish body plan and the convergent morphological features seen in the evolution of tetrapods."

The caves in Thailand where the fish was discovered

Unlike most fish, *C. thamicola* can walk on dry land

THEY DID WHAT?!

CHICKENS GIVEN DINO LEGS

What did they do?

A team from the University of Chile has grown chicken embryos with 'dinosaur-like' lower legs. In modern-day birds, the

fibula – the thin bone found in the lower leg – is splinter-like and doesn't reach all the way to the ankle. Dinosaurs' fibulae, in contrast, were much more developed.

How did they do that?

By inhibiting the activity of a gene going by the rather bizarre name of 'Indian Hedgehog'.



Why did they do that?

Around 66 million years ago, most dinosaurs went extinct, but a handful of species survived. These went on to evolve into the birds we see today. The researchers are trying to use 'reverse evolution' techniques to find out how this transformation took place.

IN THEIR OWN WORDS

"It could be the first hint of a better, bigger theory that the Standard Model would be embedded in"

Has a new particle been found at CERN?

Four years after the discovery of the Higgs boson, a new particle may have been uncovered at CERN. GRAHAM SOUTHERN spoke to JON BUTTERWORTH, a member of CERN's ATLAS detector team

How did experiments reveal these hints?

The Large Hadron Collider [LHC] collides protons [hydrogen nuclei] head-on and we discovered the Higgs boson in those collisions. This new thing has shown up in the data taken since then. We've cranked up the energy, which means you can

create higher mass particles more often because $E=mc^2$. The way the experiment works is that you count the number of pairs of photons [particles of light]. Most of them come from random collisions and there's a smooth distribution of masses. But if there's a new particle in there, there'll be a

concentration of these pairs of photons around the mass of the new particle.

What have you seen this time?

It seems like there's another concentration of pairs of photons clustered around [an energy of] 750GeV, about 750 times the mass of the proton or roughly six times the mass of the Higgs boson. It's much heavier, but in another sense the evidence is rather similar to that for the Higgs. The evidence is about at the level that it was for the Higgs about six months before we announced it.

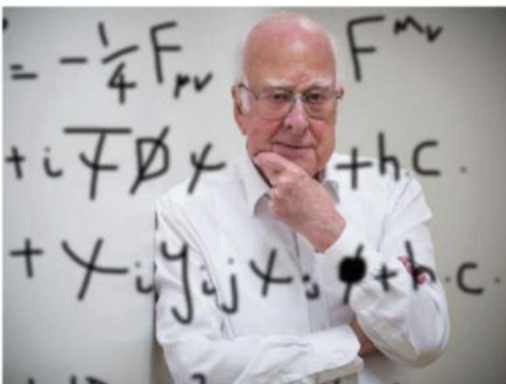
When will we know for sure this time?

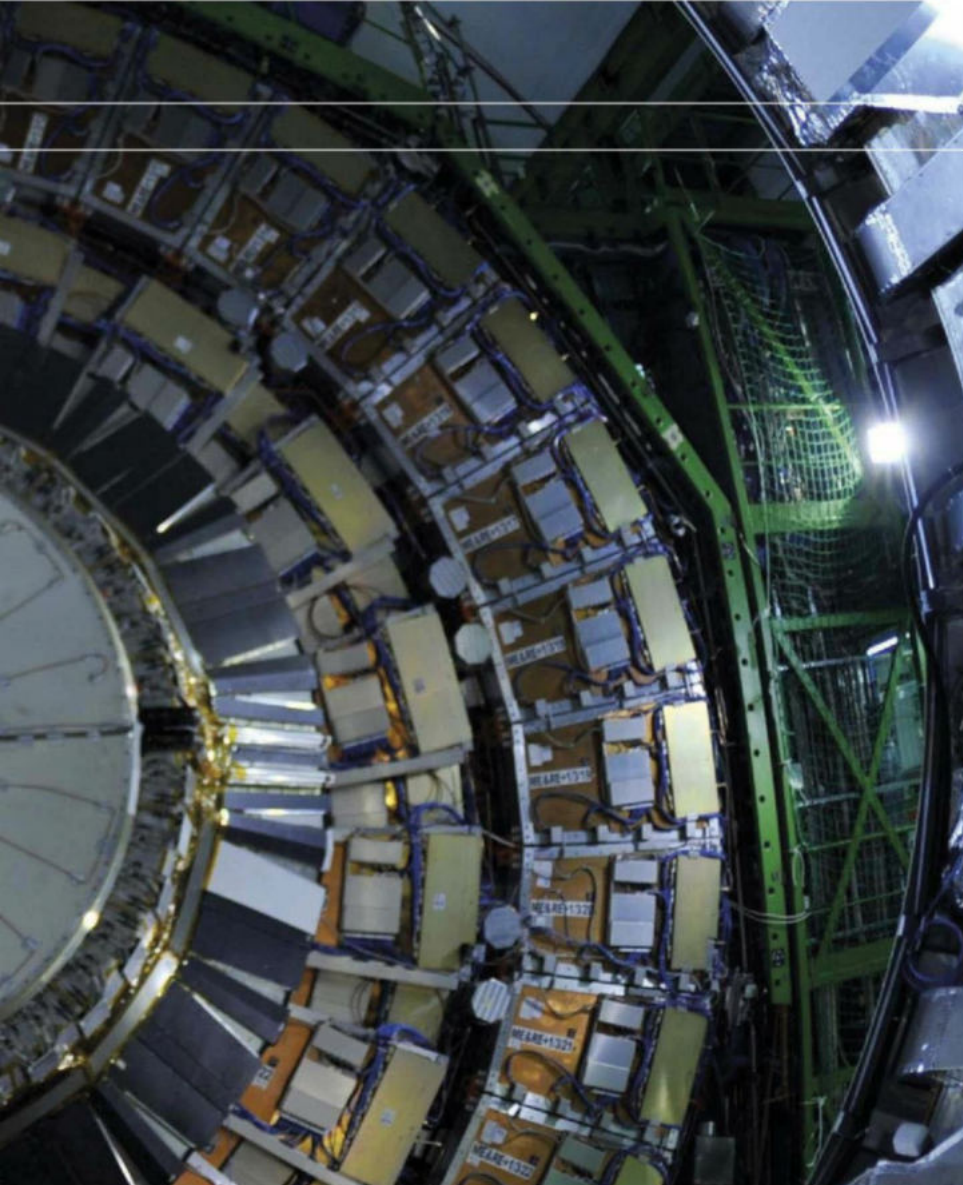
If all goes to plan, I would expect an announcement sometime in the summer conferences. It will either have grown to the point where there's a discovery, or it will have receded a bit and we'll be less excited. It's like looking at an object in the mist. As you get closer, it either gets clearer or it fades away and turns out to have just been a swirl in the mist.

What are the implications for physics?

It's really exciting because this is not something

BELOW: Prof Peter Higgs predicted the Higgs boson – the 'God Particle' – back in the 1960s, but it wasn't discovered until 2012 at the Large Hadron Collider





BLONDES

Who are you calling a dumb blonde? A study at the Ohio State University has found that blonde women have marginally higher average IQs than brunettes or redheads and are more likely to be classified as geniuses. But don't bother reaching for the bleach – the effect was only seen in natural blondes.

SUN WORSHIPPERS

Here's an excuse to get away somewhere sunny: Swedish researchers have found that catching some rays may help extend your life. However, sunbathing for long periods can cause skin cancer so don't stay out for more than half an hour.

GOOD MONTH

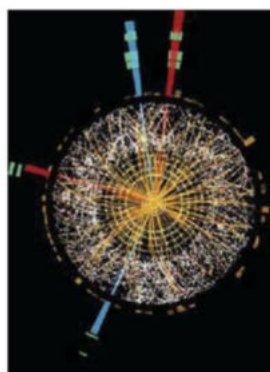
BAD MONTH

REALITY TV FANS

If you find yourself keeping up with the Kardashians, you may be a narcissist. University of Pennsylvania researchers have found that reality TV fans score more highly on the Narcissistic Personality Inventory.

CAT OWNERS

Next time you see someone flipping off another driver, blame Tiddles. People suffering from intermittent explosive disorder, a condition that causes aggressive outbursts such as road rage, are more than twice as likely to be infected with *Toxoplasma gondii*, a parasite carried by moggies.



TOP: Experiments at the Large Hadron Collider are helping scientists gain a deeper knowledge of physics

ABOVE: Collisions between protons at the Large Hadron Collider are once again being analysed in the hunt for a new particle

that's expected in the Standard Model – in fact it's excluded by the Standard Model! So it could be the first hint of a better, bigger theory that the Standard Model would be embedded in. The bigger theory would have a chance of answering questions that the Standard Model doesn't answer, such as what is dark matter, how does gravity fit into the picture, and why is there more matter than antimatter in the Universe? Despite having proved that the Higgs was there, the Standard Model doesn't answer those questions so it's clearly not any kind of final word on fundamental physics.

If it is confirmed, what would you do next?

The theorists are having a heyday already. They're building all kinds of hypotheses to answer some of the open questions, using this [potential particle] as a clue. It's like you've filled in a new word in a crossword puzzle that gets you into a corner of the puzzle you've not been in before. Most of those hypotheses will say, 'If my theory is right, not only do you see this thing, but if you look over there you can see another thing'. All of these theories have consequences for other measurements we can make at the LHC. As experimentalists, we'll be weeding out the ones that don't work and hopefully zooming in on the few that do.

SPECIAL REPORT

LANDMARK STUDY REVEALS THE EFFECT OF LSD ON THE BRAIN

For the first time, scientists have used brain scanners to uncover what happens in the brain under the influence of LSD, more than 70 years after the drug was first synthesised. Zoe Cormier investigates

A team led by Imperial College's Prof David Nutt has discovered that brain networks become 'desegregated' under the influence of LSD (also known as 'acid'). Regions of the brain that do not normally communicate with each other suddenly do so.

"The brain becomes much more integrated in a strange sort of way," said Nutt. "You can pull together things that you wouldn't normally. This is why LSD could be so powerful in treating conditions where the brain has become 'locked in', such as alcoholism or depression."

"You get increased connectivity because you have dampened down the control centres," added researcher Robin Carhart-Harris.

The team picked 20 subjects who had previously used psychedelics, to minimise the risk of them having a bad experience. Each was given LSD, then spent an hour in an MRI scanner while three different imaging techniques gathered data. They were then put through a number of cognitive tests.

Tom Shutte was one of those brave enough to take LSD in a claustrophobic brain scanner. "Every now and then I did think, 'What am I doing in here?'" he said later. "Sounds were really unpleasant, loud, unpredictable and aggressive. Sometimes it took a lot of willpower to keep it together. Plus,

some of the questions were very strange: 'Did your ego dissolve?' Ultimately, if me spending a difficult hour in a scanner in Cardiff can help someone suffering acute trauma down the line, it's worth it."

Beyond investigating the use of psychedelics as medication for ailments such as post-traumatic stress disorder, depression and addiction, the ultimate purpose of this work is probing the nature of

**"THE ONLY
WAY TO STUDY
CONSCIOUSNESS IS
TO CHANGE IT"**



Prof David Nutt led the research into the effects of LSD on the brain

consciousness itself, explained Nutt. "This is core neuroscience. It is about humanity at its deepest level. And the only way to study consciousness is to change it."

Others are yet to be convinced. "This study doesn't tell us much about the therapeutic value of this drug, though it may give us suggestions to investigate further," said Glen Hanson, former acting director of the US National Institute On Drug Abuse, who's published over 150 scientific papers exploring how drugs affect the brain. "But LSD is a very dirty drug: it is not particularly selective in what it does. As a result, it can be problematic for patients with underlying psychiatric disorders."

Organisations that fund academic and medical research seem to agree with Hanson. Nutt's team found it extremely hard to acquire funding, and eventually turned to crowdfunding to raise the money. This ended up being a roaring success, with 1,628 people donating £53,390 to the cause, double the £25,000 asked for.

A BRIEF HISTORY OF LSD

The story of LSD, or lysergic acid diethylamide, began in 1943 when chemist Albert Hofmann was tinkering in the laboratories of Swiss pharmaceuticals company Sandoz. He was developing drugs to treat blood loss following childbirth. When his fingers touched a bit of

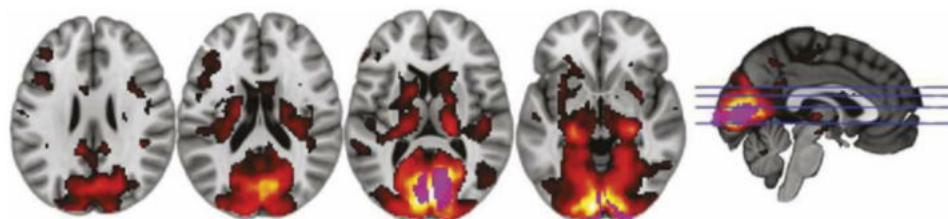
Volunteer preparing to enter the scanner

PHOTOS: GEORGINA CAMMALLER, JIRI REZAC / EYEVINE

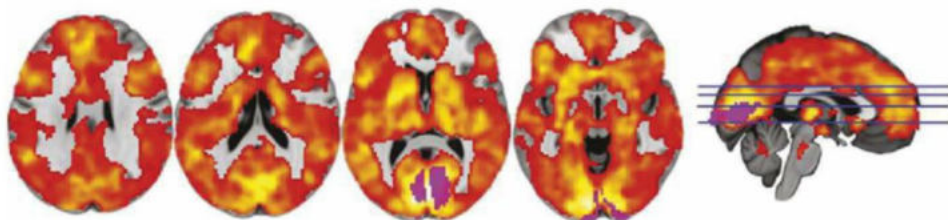


LSD
is a class-A
drug and is
illegal in the
UK

PLACEBO



LSD



The orange colouring shows areas of the brain experiencing increased resting-state connectivity

LSD-25 – a drug he'd first synthesised five years earlier – the world began to shimmer. With such a profound capacity to change the way we see, feel and think, Hofmann believed LSD could become a valuable psychiatric tool.

For a time, his peers agreed. Psychiatrists around the world deployed the drug in their quest to understand the human condition, exploring it as a treatment for conditions such as schizophrenia and alcoholism. Of course, many scientists yearned to understand what was going on in the brain itself, but these were early days for neuroscience: the MRI scanners we now use to study the brain did not appear until the 1970s.

A few studies measuring the electrical activity inside the brain using electroencephalogram (EEG) readings found reductions in the activity of the brain under LSD. But before anyone could delve deeper, research ground to a halt, as the US and other countries banned the drug from 1966.

In 2012, Carhart-Harris published a study of the brains of people who had been dosed with the hallucinogen psilocybin. Counterintuitively, he found that the drug decreased, not increased, the flow of blood to a constellation of regions known as the 'default mode network', considered by some to be the 'seat of the self'. In a normal state, these regions are crucial to keeping our experience of the world stable.

Similarly, Dr Draulio de Araujo of the Brain Institute at the Federal University of Rio Grande do Norte in Brazil has studied the effects of the hallucinogenic brew ayahuasca, and found that the drink – which contains the potent psychedelic DMT – also reduces blood flow to the default mode network. "This important because in depression we see the opposite pattern," he said. "So this gives us clues as to the potential use of psychedelics as antidepressants."

With the initial study finished, Nutt is sure LSD will be "invaluable" in helping us understand the nature of the sober mind, consciousness and the brain. "To paraphrase Isaac Newton: we can see further because we are standing on Hofmann's shoulders," he said.

DISCOVER MORE



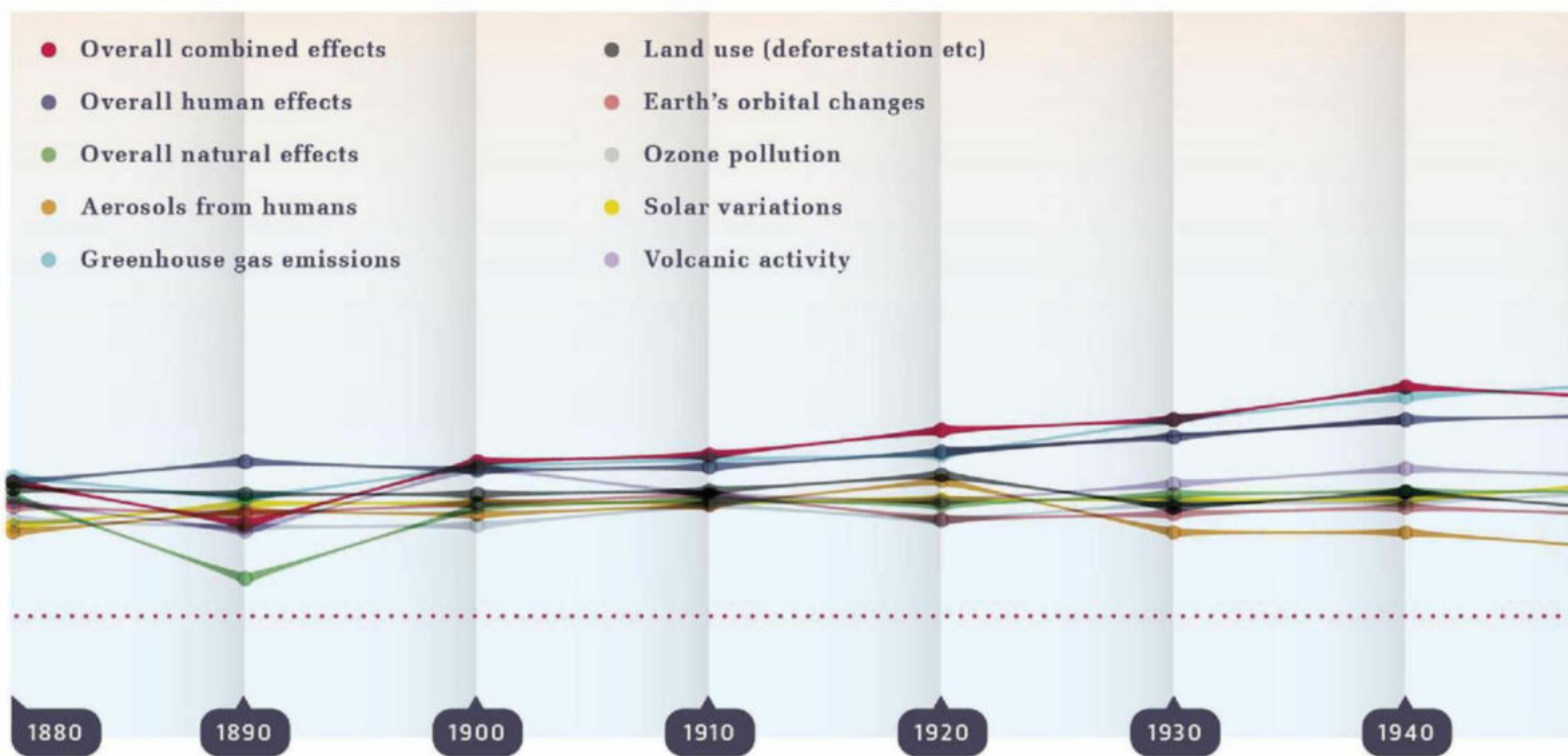
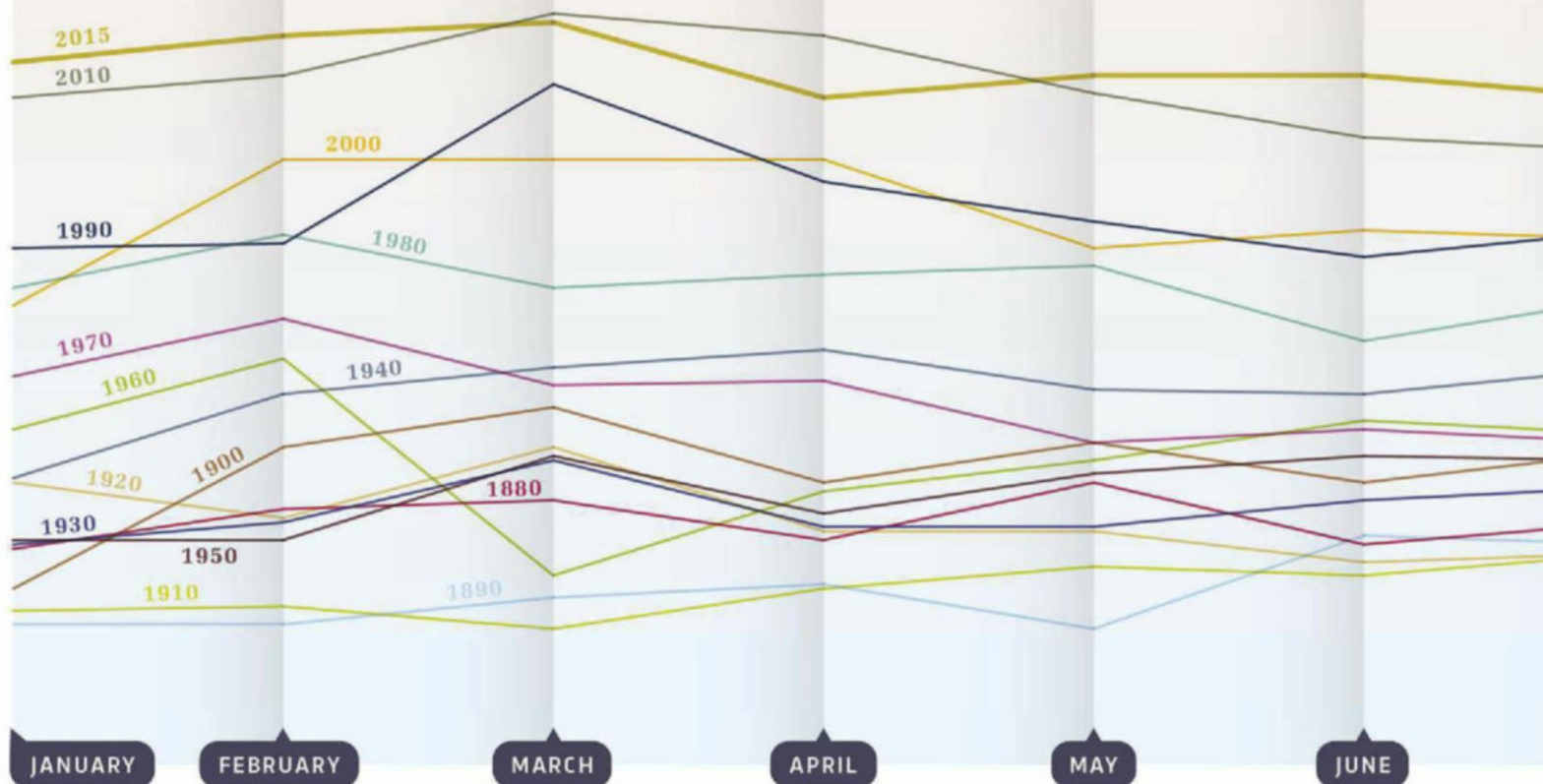
To read the full story about this landmark LSD study, visit bit.ly/LSDeffects

WHAT'S WARMING UP THE PLANET?

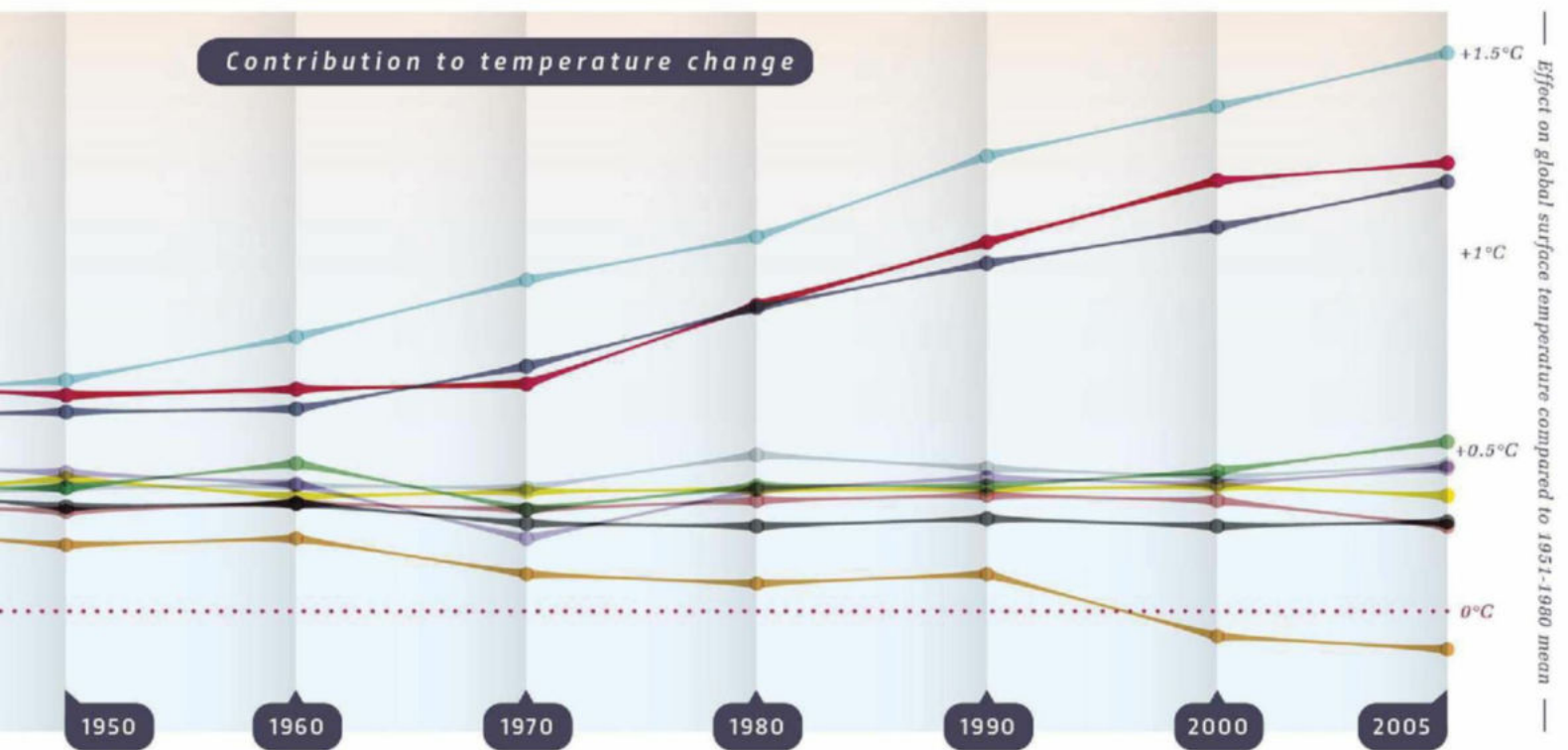
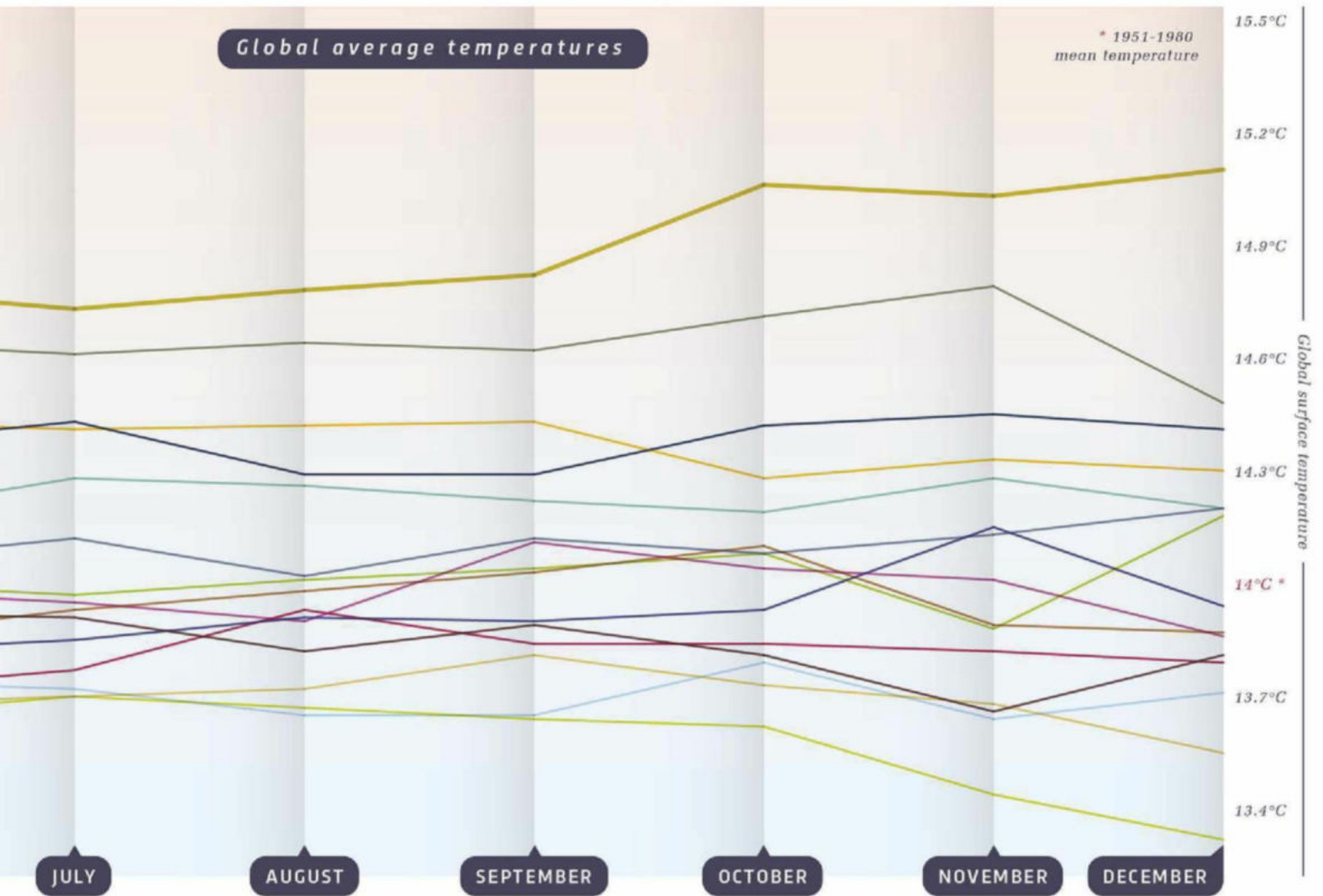
Illustration: Valerio Pellegrini

2015 was the hottest year since records began. But what's driving this change? NASA might have the definitive answer. The Goddard Institute for Space Studies has built a climate change model that allows

them to isolate potential culprits and estimate their contributions. We've plotted their data below to illustrate how natural variables like volcanic activity and solar variations compare with man-made factors.

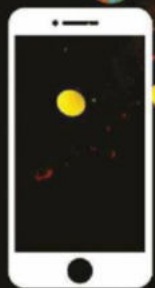


DATA SOURCE: DATA.GISS.NASA.GOV/MODELE



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HASTA LA PIZZA, BABY

Could a new robot spell the beginning of the end for the delivery guy?

Domino's, the world's largest pizza chain, has begun trialling robot delivery of its pizzas in Wellington, New Zealand. The robot in question is known as DRU, which stands for Domino's Robotic Unit. Developed by Domino's in conjunction with Australian robotics company Marathon Targets, it stands a metre high, travels on four wheels and can reach speeds of 20km/h (12.4mph), travelling on pavements and cycle paths rather than on the road. It's



DRU keeps your pizza hot and your drinks cold, so you can tuck in as soon as it arrives

equipped with Domino's own GPS tracking system, and has a LIDAR system of laser sensors that enables it to detect pedestrians, cyclists and any other obstacles in its path. There are also on-board cameras and an alarm system that could be linked to local police, to deter any would-be thieves.

The bot can deliver pizza within a 20km (12.5-mile) radius of its shop, and contains two storage compartments: one for hot food, the other for cold drinks. Once it reaches its destination, customers are sent a security code which enables them to open the locked compartments and access their food. The DRU made its first successful pizza delivery on 8 March, and plans for wider testing are currently being put in place.

In a statement, Domino's general manager for New Zealand Scott Bush said: "DRU is cheeky and endearing and we are confident that one day he will become an integral part of the Domino's family. He's a road to the future and one that we are very excited about exploring further."

New Zealand's transport minister Simon Bridges, who worked with Domino's on the

research, said: "This is an exciting opportunity for New Zealand. Over the last 12 months I've been actively and aggressively promoting New Zealand as a test bed for new transport technology trials."

DRU isn't the only autonomous delivery system being tested, of course. Amazon's delivery drones have made headlines in the press, while UK/Estonian start-up Starship Technologies, which was set up by two of Skype's founders, has also been prototyping and testing a delivery bot.

It may be some time before we see DRU or his cousins beetling about the streets, but its arrival is another sign that a future in which many more tasks are carried out by automata rather than

people is swiftly moving from sci-fi fantasy to reality. Whether that's a good or a bad thing is, of course, a debate for another day.

But whatever your opinion, we're sure DRU will be happy to have moved on from his old job – Marathon Targets originally developed the robot as a base for soldier mannequins used in live ammo target practice for soldiers. And being shouted at because someone got thin crust instead of deep pan beats getting shot at any day of the week.

**"WE ARE CONFIDENT
THAT ONE DAY HE
WILL BECOME AN
INTEGRAL PART OF THE
DOMINO'S FAMILY"**

NEWS BYTES

RELEASE THE CRACUNS

A team at Johns Hopkins University has built a flying drone that can live underwater. It's intended as an extra 'pair of eyes' for submarines and has been dubbed CRACUNS (Corrosion Resistant Aerial Covert Unmanned Nautical System).



TINY HARD DRIVE

Western Digital has created a 300GB hard drive that's just 6.35mm (0.25in) thick. PiDrive is aimed, as the name suggests, at users of the Raspberry Pi and will retail for just £39.50.

FASTER INTERNET

A MIT team has designed a way to make web pages load up to 34 per cent faster. The system, Polaris, minimises the number of times your computer has to communicate with a remote server to display a page.

CHEVY SAFETY

The latest Chevy Malibu includes a 'teen driver' mode designed to put anxious parents at ease. It issues warnings about speed and seat belts, but also feeds back data on their driving to parents via an app.

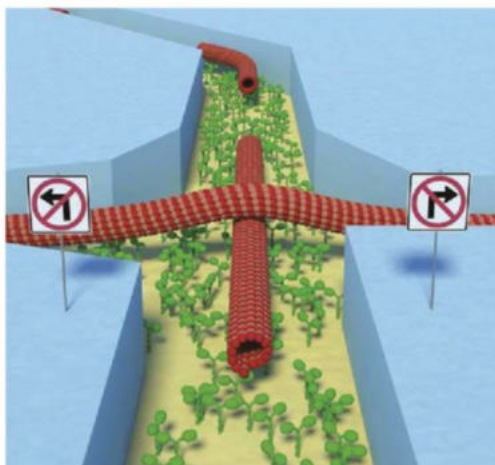


SOLAR 'BATTERIES' FROM CO₂

General Electric is developing a system to capture CO₂ from fossil-fuel power plants, freeze it, store it, and then heat it – using excess energy from solar power plants – to drive power-generating turbines.

ENGINEERING

First biological supercomputer built



Visualisation of McGill University's biological supercomputer

A team at McGill University in Montreal, Canada has built the world's first working biological supercomputer.

The project was the brainchild of Prof Dan Nicolau, chair of the university's Department of Bioengineering, who has been developing the idea for over a decade, aided by his son (Dan Nicolau Jr) and researchers from Germany, Sweden and the Netherlands. The supercomputer works by placing short strings of proteins into channels etched onto a 1.5cm² chip. The proteins move around the chip powered by adenosine triphosphate (ATP), the enzyme which gives energy to cells within living beings.

Using this method, the Nicolau duo and their colleagues were able to build a parallel network that successfully solved problems that would normally require a supercomputer. The difference is that McGill University's machine is much smaller than a typical supercomputer, requires far less energy to work and doesn't heat up (and so doesn't require cooling).

These are, however, still early days, as Nicolau Sr admits. "It's hard to say how soon it will be before we see a full-scale bio supercomputer," he said. "One option for dealing with larger, more complex problems may be to combine our device with a conventional computer to form a hybrid device. Right now we're working on a variety of ways to push the research further."

MUSIC

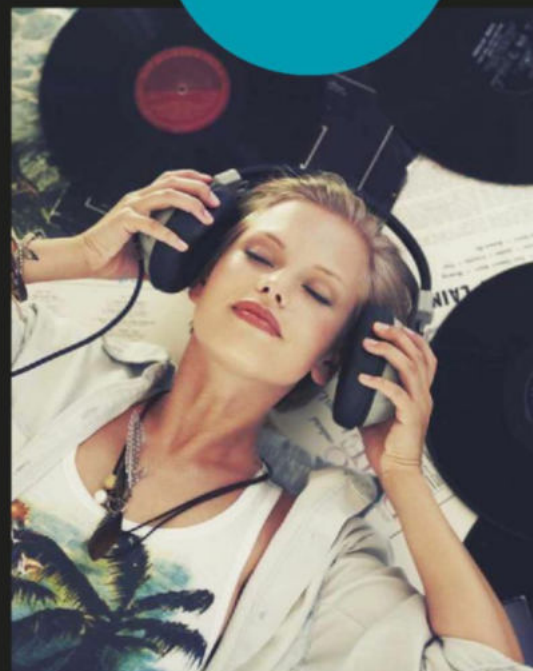
Vinyl reinvented... in HD form

With the vinyl revival in full swing, an Austrian company, Rebeat, has filed a patent for a new high-definition vinyl format that will play on standard turntables, yet offers improved sound quality, 30 per cent greater capacity and higher playback volume.

The tech for which it's filed a patent – known for now as 'HD vinyl' – involves using 3D topographical mapping and laser inscription to create discs which, as well as having the advantages listed above, can be manufactured more quickly than those made using traditional 'stamping' methods.

Rebeat is now looking to extend its EU-wide patent into a global one, after which it hopes to start creating HD vinyl discs for real – hopefully within two to three years.

Vinyl upgraded



HEALTH

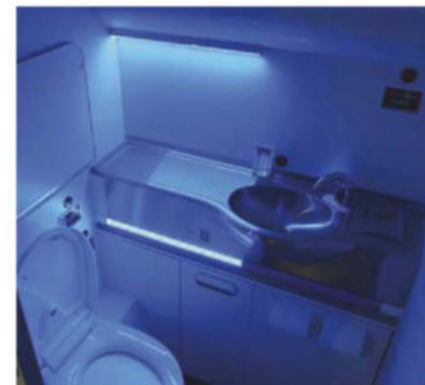
Plane toilet horrors reduced with UV light

There are lots of things to love about flying, but a trip to the loo on a crowded 747 isn't usually one of them. However, the days of smelly, unhygienic cubicles may be numbered, as Boeing has invented a self-cleaning bathroom.

The design, for which Boeing has filed a patent application, makes use of 'far UV' light. This light matches the resonant frequency of the molecular bonds that hold microbes together, causing the germs to explode. The technique is said to destroy 99.99 per cent of all known pathogens, and remove unpleasant odours in a mere

three seconds. Lights are placed throughout the toilet compartment to ensure the UV reaches all surfaces – the toilet lid even opens and closes itself while cleaning is going on to make sure there's no safe haven for germs to hide.

UV light zaps the surfaces in the Boeing's toilets to leave it with fewer germs and smelling sweeter



WANTED!

LACE UP, LOOK SHARP

NIKE HYPERADAPT 1.0

Self-lacing trainers – as featured in the cult movie *Back To The Future II* – are finally a reality. Nike, which made an extremely limited-edition run of self-lacing shoes in 2015, has now unveiled the Hyperadapt 1.0 shoe, which features “electro-adaptive reactive laces”. The battery-powered system uses weight sensors in the sole and a system of pulleys which can be controlled with a button on the top of the shoe. Battery life is said to be about two weeks, but the shoes also contain a wireless charging system.

[ETBC, nike.com](#)

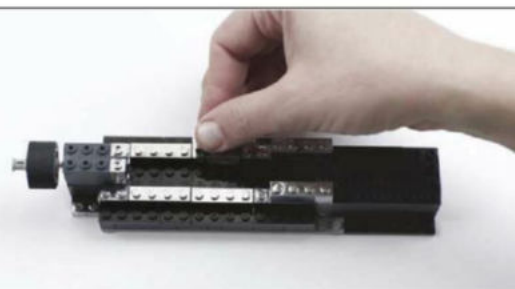


BETTER BRICKS

BRIXO

These chrome-plated building blocks transform your Lego bricks into an electrical engineering set. ‘Trigger’ blocks contain sound, light or proximity sensors or Bluetooth transceivers, ‘action’ blocks contain lights or motors, and connector blocks link the two, while power is supplied from a Bluetooth-controlled, low-voltage battery block. Join them together and you can build vehicles that actually move, models that light up when someone speaks or, well, whatever else you can think of.

[From \\$50, getbrixo.com](#)



MINIATURE MAGNETIC MARVEL

PANASONIC CIO

Induction hobs, which heat pots and pans by magnetically inducing an electrical current, have been around for a long time, and are popular with chefs because they’re quick and efficient. So far the technology’s been restricted to hobs, but now Panasonic has unveiled the CIO (the initials stand

for ‘countertop induction oven’), an induction cooker that’s no bigger than the average microwave. Ideal for students or those living in ‘compact’ city apartments, the CIO will be available from October, though there’s no word yet on price.

[ETBC, panasonic.com](#)



RADIO MAKES WAVES

LG STYLUS 2

DAB radio has been around for years, yet smartphone makers have continued to fit their devices with old-fashioned FM. LG is changing that with the introduction of the Stylus 2, the first smartphone to feature built-in DAB+ radio (a version of DAB

that uses AAC rather than MP2 encoding). Available in Europe and Australia, but not in the US where the rival FM HD radio system holds sway, the Stylus 2 also features a 5.7-inch display, a 1.2GHz quad-core chip, 1.5GB of RAM and a 13MP camera. [ETBC, www.lg.com](http://ETBC.com)



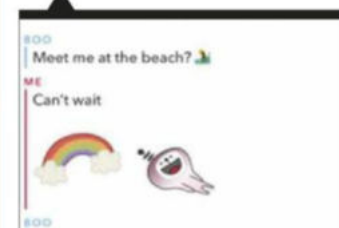
APP FEED



Snapchat

Recently updated, the messaging app's Chat 2.0 lets you send stickers, emojis, photos and vids in two-way conversations.

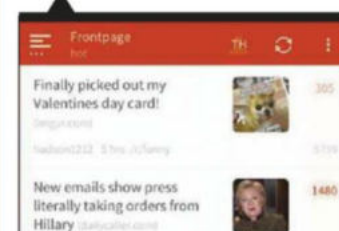
Free, iOS/Android



Redditify

With iOS boasting the only official app, this reader is ideal for keen Reddit users using Android or Windows devices.

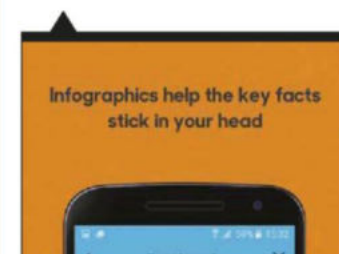
Free, Android/Windows



BBC Bitesize

The app version of the BBC's learning platform Bitesize, designed to aid youngsters up to GCSE level with their revision.

Free, iOS/Android



Bin your rubber gloves



IT'S A DIRTY JOB...

BRAAVA JET 240

New from iRobot, maker of the Roomba robot vacuum, comes the Braava Jet 240 robot mop. It isn't iRobot's first venture out of the living room into the kitchen, but at just \$200 the Braava Jet 240 is roughly a third of the price of the company's previous robot mops. The mop sprays the floor with a jet, then scrubs and dries it with cleaning pads, all while using advanced AI to navigate its way around the room. There's also a 'dry' mode for simple sweeping and dusting.

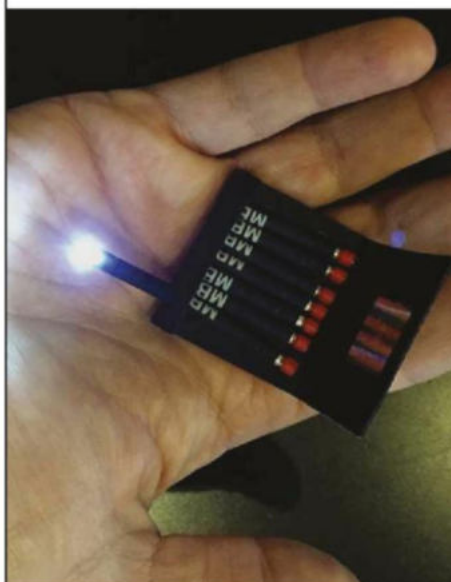
\$200 (£140 approx), irobot.com

STRIKE A LIGHT

MBI MATCHBOOK

Aimed at trekkers, mountain climbers and other outdoors-y types, the MBI Matchbook is a set of tiny LED torches cunningly disguised as a book of matches. Each of the eight torches will shine for around eight hours once activated, which you do by hitting the tip against a hard surface – much like striking a match, in fact! The other end is magnetic, so you can affix your miniature beacon to nearby metal objects (such as a tent pole or the chassis of a vehicle) if you need to, and they're available in red, white or green.

\$45 (£32 approx), www.matchboxinstruments.com



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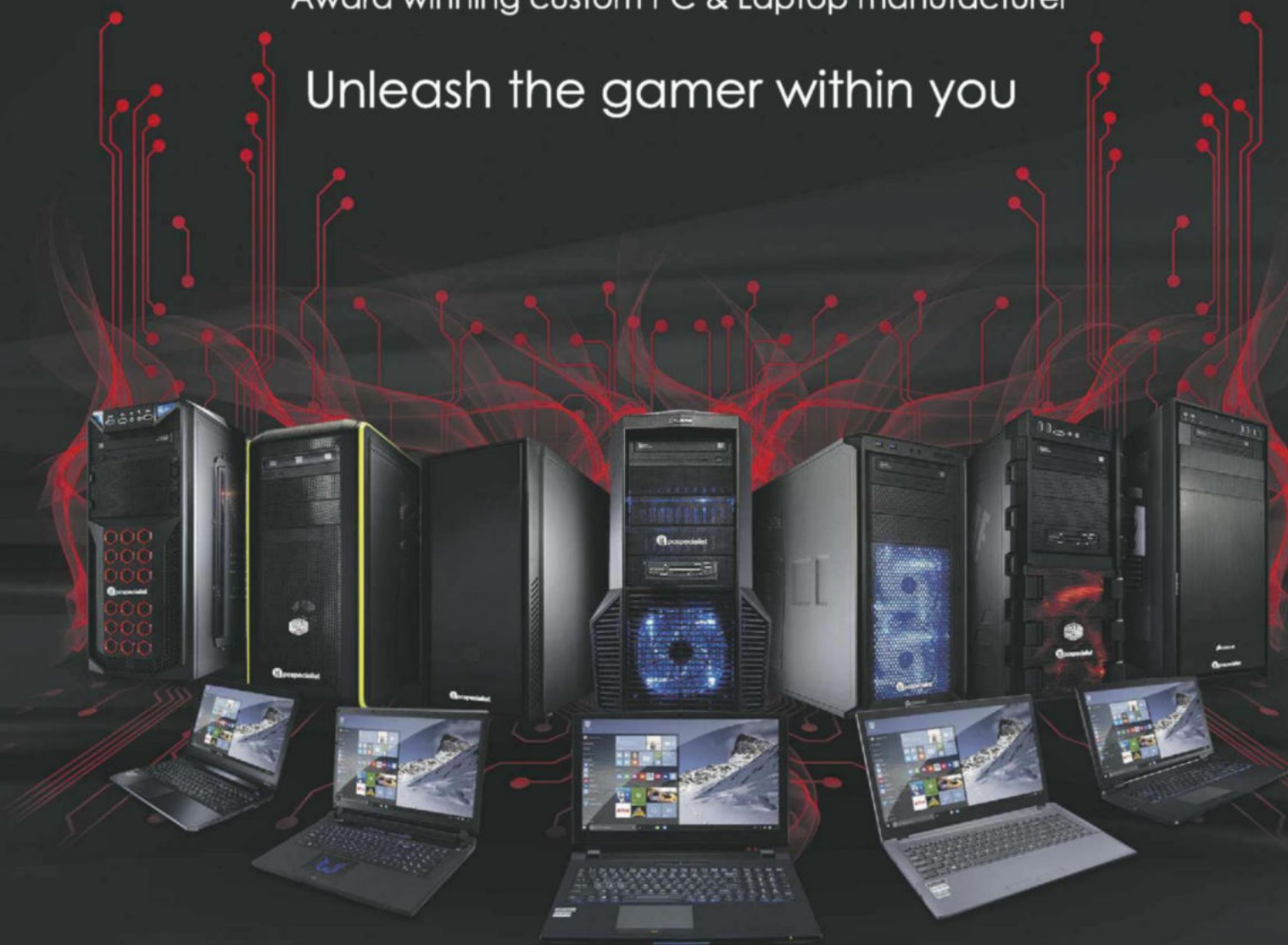
Some features require Windows 8.1. Update available through Windows Store. Internet access required; fees may apply. Microsoft, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

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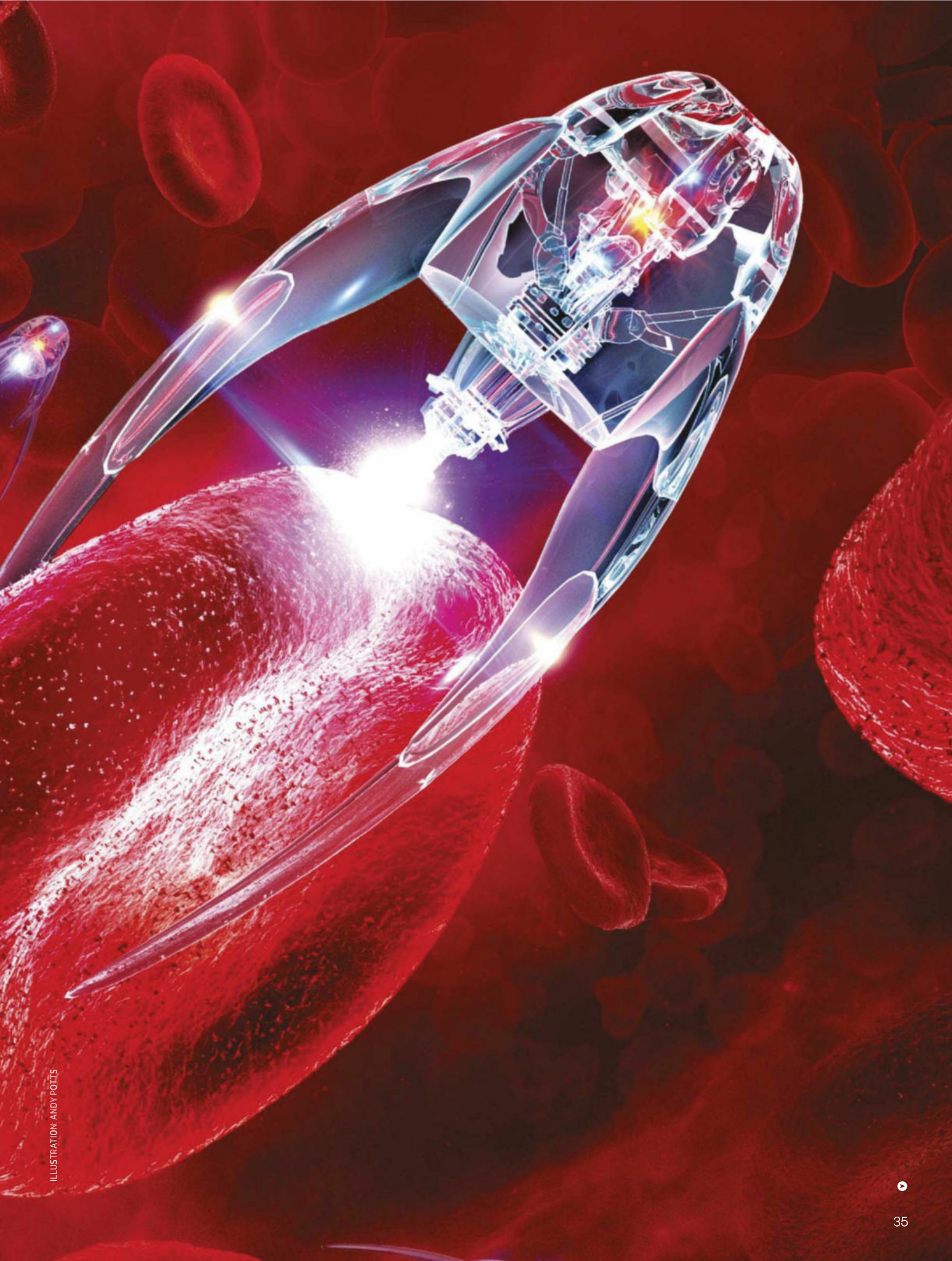
www.pcspecialist.co.uk

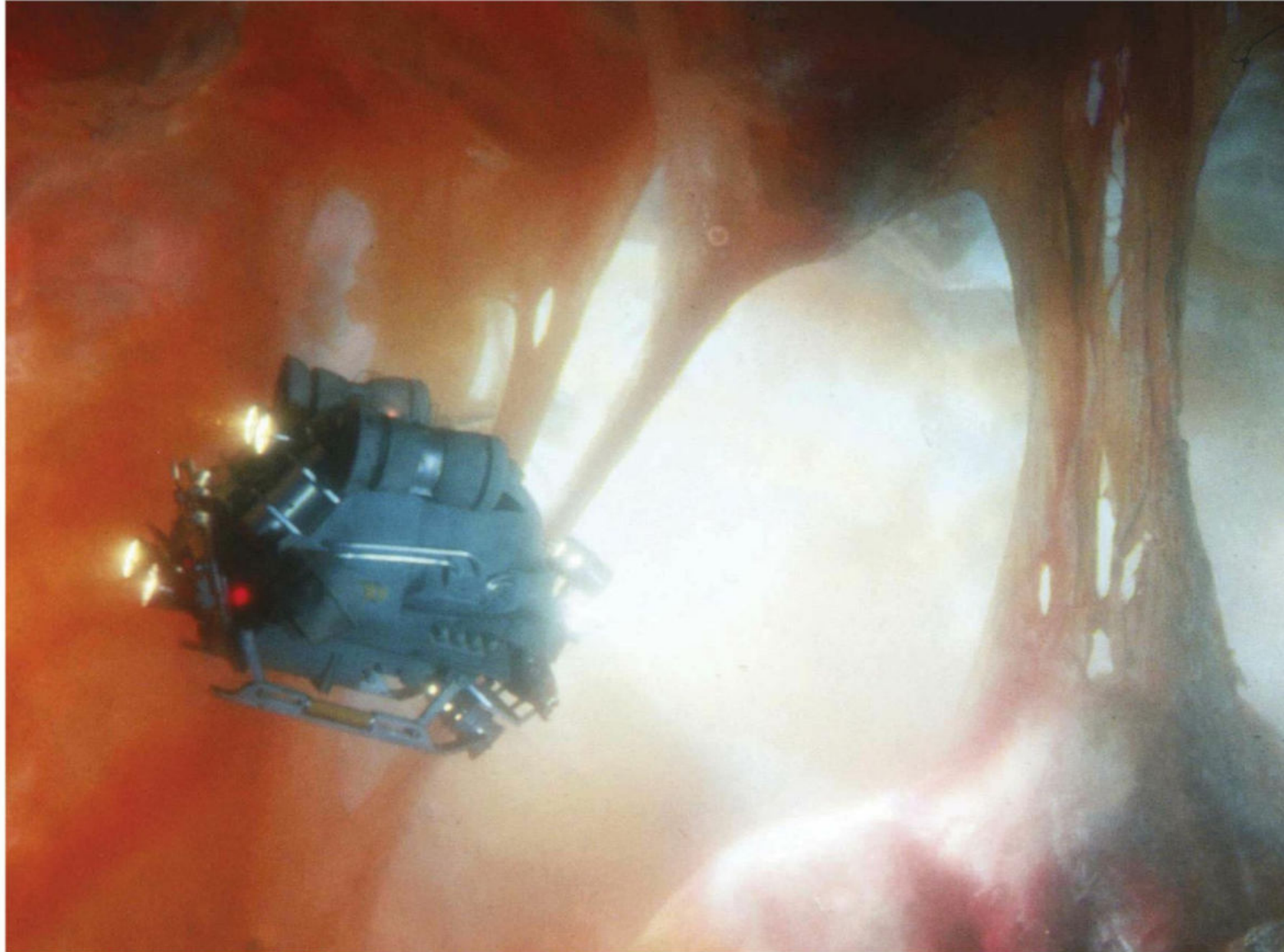


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Words: **Tom Ireland**





ABOVE:
The plot of
sci-fi film
Innerspace no
longer seems
quite so
outlandish

T

he 1980s sci-fi film *Innerspace* sees a submersible and its pilot shrunk to microscopic size before being jabbed into a shop attendant, and much hilarity ensues.

The plot took its inspiration from 1960s classic *Fantastic Voyage*, in which a miniaturised crew are injected into a dying scientist and must attempt to remove a clot from his brain.

Both films seemed pretty crazy when they came out, but the extraordinary ideas featured no longer seem quite so far-fetched. Tiny cameras can now be swallowed, while electrodes can be placed deep within the brain. And increasingly, nanotechnology tiny enough to be injected into the bloodstream is the focus of new treatments for diseases like cancer.

These ingenious devices are expected to revolutionise medicine in the coming decade – they're small enough to flow through the body's tiniest blood vessels, yet are packed with

“Diabetics could simply shine a torch on their arm to top up their insulin”

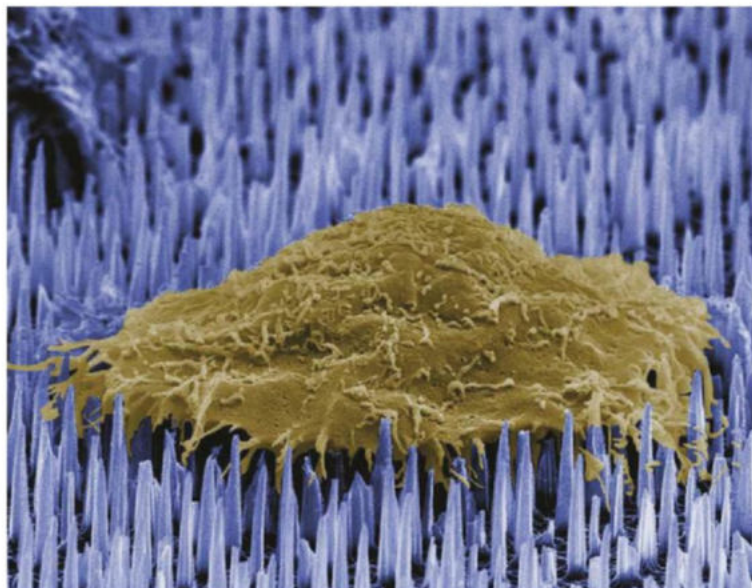
technology smart enough to find and treat the causes of diseases.

SMALL SCIENCE

The simplest nanomedicines are spherical particles that carry a payload of drugs. Smaller than human or bacterial cells, but larger than individual molecules, the spheres are tiny enough to penetrate cells. The term ‘nano’ is used to describe objects smaller than 100 nanometres, with one nanometre being a billionth of a metre. Particles at this scale have different properties than if they were larger.

Nanomedicines are large enough to stay in the bloodstream for longer than normal medicine molecules, yet they are not so big that they clog up blood vessels. Scientists can even attach biological molecules to the outside of nanoparticles to ensure, for example, that they are attracted to specific molecules in the body – such as those found in tumours. Or, by making nanoparticles with more complex shapes, scientists can effectively create tiny machines that use chemical reactions to become unimaginably small motors or light-emitting globes. Some nanomachines can even puncture a hole in cell membranes, much like how a virus injects its DNA to infect a host cell.

By putting these elements together – payload delivery, molecular recognition and pore



puncturing – scientists can create vessels capable of travelling to the site of a tumour, for example, and treating it directly.

ON TRIAL

Only around a dozen nanomedicines are licensed for use at the moment, but hundreds more are in development or undergoing clinical trials.

Imagine, for example, being able to release drugs into your body by shining a torch onto your arm rather than having an injection. Well, researchers at the University of California, San Diego might just have made that a reality. They've developed ball-shaped nanoparticles made from a polymer that falls apart when UV light is shone on it. This simple system means the nanoparticles release their medical payload wherever light is shone into the body. The researchers foresee a time when diabetics could shine a torch on their skin to top up insulin.

Meanwhile, a microscopic, injectable 'nanoparticle generator' was recently found to yield 'astonishing results' in the treatment of lung and liver cancers in mice. These drug-filled containers can deliver higher doses of drugs to the cancerous cells than medicines dissolved in the blood. Healthy tissue is therefore spared the toxic effects of a high dose. Clinical trials on the first human patients could begin as early as next year. ●

TOP: A single human cell rests on a bed of nanoneedles

ABOVE: Quantum dots can be engineered to emit light at specific wavelengths

THE NANO TOOLKIT

How do you make a machine that's small and smart enough to travel into the body and blast a tumour?



POLYMERS

Polymers are materials that form hollow balls that can then be filled with tiny amounts of other useful chemicals.



GRAPHENE

A type of carbon that forms sheets just one atom thick. The material is strong and highly unreactive, so can be used to create a range of tiny objects.



CARBON NANOTUBES

Sheets of graphene rolled up into tiny tubes ('nanotubes') have been a key component in nanotechnology for years. These tubes could be used on the ends of 'nanoneedles', allowing them to inject substances into specific areas of individual cells.



QUANTUM DOTS

Quantum dots are tiny spheres that are small enough to pass freely through cells. They have a metal inner core and an outer casing. Some emit light, which can be used signal the presence of disease.



DNA

DNA's ability to self-assemble into complex shapes makes it an ideal material for making devices on a tiny scale. Scientists have already created DNA-based shapes that can act like tiny motors or boxes.



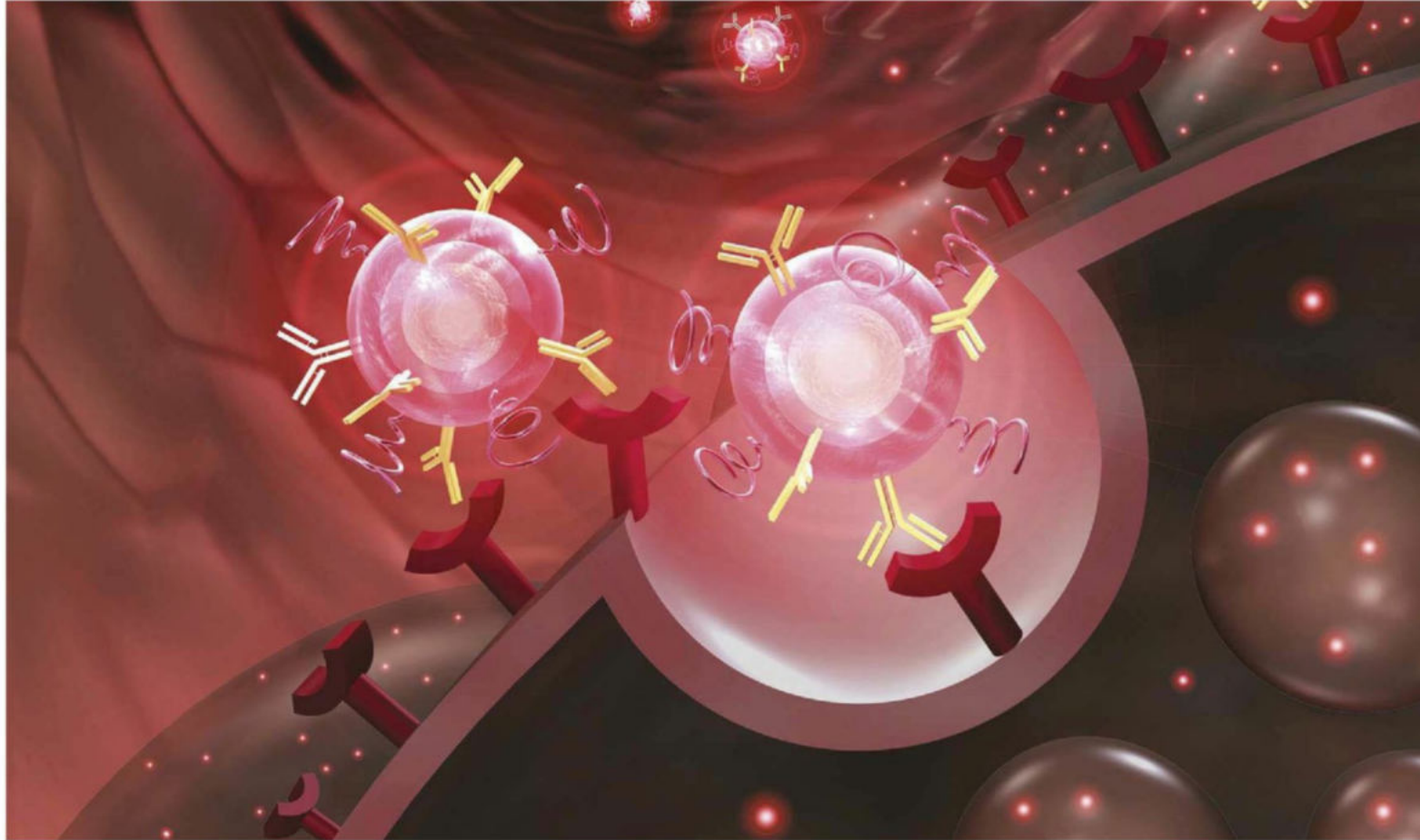
PROTEINS

Like DNA, proteins are capable of assembling themselves into large, complex, and highly predictable shapes. New shapes and functions can be designed by altering the sequence of subunits from which the proteins are made.



VIRUSES

Viruses are nature's own nanomachines. Barely considered living organisms, they are often made of just a few proteins and strands of DNA. Yet they can still infect host cells to make copies of themselves. Bolting useful medical functions onto existing viruses is a promising area of nanomedicine under development.



• Nanomedicine is not just about the delivery of drugs through the bloodstream. There are numerous other ways nanotechnology could transform medicine, says Prof Kostas Kostarelos, chair of nanomedicine at University College London. He is helping to develop ‘nanoneedles’ that could extend surgeons’ tools to unimaginable levels of fineness and precision.

“This could offer surgeons an extension of the syringe or scalpel at the nanoscale, which could deliver therapeutics to individual cells, or even allow them to manipulate individual cellular components,” says Kostarelos. “They would use molecular recognition so that the tip associates with a particular structure.”

Scientists also believe nanomedicines will be used to send signals about conditions in the body. For example, nanoparticles known as ‘quantum dots’ have a metal inner core and a protective shell. This structure gives them unique optical properties, allowing the particles to be modified so that they can give off fluorescent light in the presence of certain disease, which is then picked up in a scan.

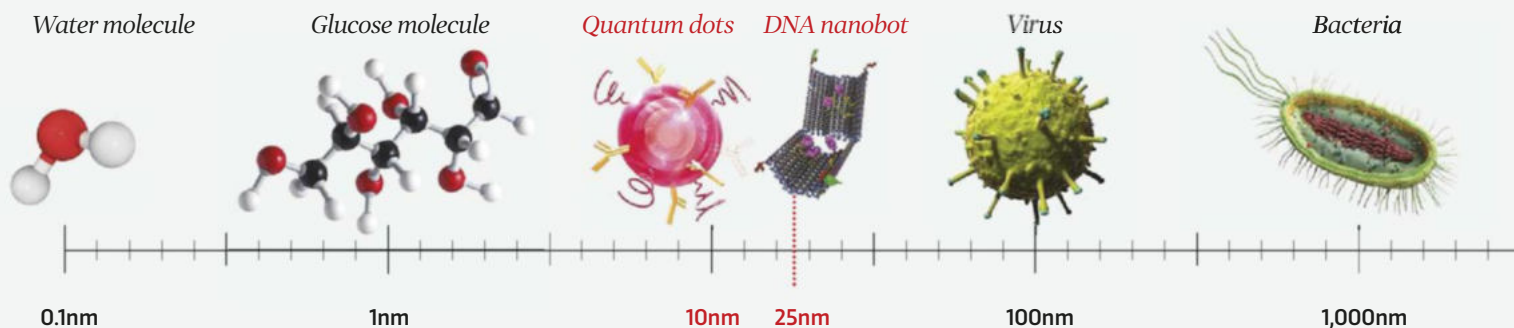
Visualisation of quantum dots attaching to a tumour on the wall of a blood vessel

MATERIAL WORLD

Nanomedicines can be roughly classified as ‘hard’ and ‘soft’ depending on the substances used to build them. ‘Hard’ nanomedicines often use materials like graphene, a type of carbon that can be made into sheets just one atom thick. These sheets can be used

SIZE SCALE (width)

Electron microscope



YOUR FUTURE DOCTOR

Could this be how nanoparticles keep us healthy in 2050?

1. Nanobots that detect signs of common diseases are injected into the blood soon after birth.

2. Signs of cystic fibrosis are detected. A modified virus 'infects' cells with gene-editing technology, repairing the genes that cause the disease.

3. On developing diabetes at 30, light-sensitive, insulin-producing quantum dots are injected into the body. To top up insulin levels during the day, a special torch is shone onto the blood vessels on the wrist, where the skin is thin.

4. At 60, a scan reveals weak

fluorescent light being emitted from deep in the lymph nodes. Nanobots are reacting with molecules found in cancer cells to signal the disease's presence.

5. To combat the cancer, more nanobots are injected into the body. They accumulate in

the tumour, making the cancerous tissue glow. Surgeons can then safely remove the tissue without the risk of damaging healthy flesh. Other nanobots are then released into the body which send powerful anti-cancer drugs directly into the cancer cells.

6. At age 90, DNA-based nanobots constantly repair the age-related damage to brain cells that can lead to degenerative conditions. Others scan the DNA in each cell to ensure it is functioning just as it used to when the body was younger.



to make tiny atomic-scale shapes such as hollow tubes and spheres, and metals with unusual properties can be embedded within them. But scientists are increasingly focusing efforts on 'soft' nanomedicines – particles made from biological materials like proteins, fats and DNA. This research takes its inspiration from the complex molecules made within all cells, many of which perform highly specific jobs and could therefore be considered 'natural nanomachines' themselves.

"Viruses can arguably be seen as nature's nanomachines"

"Nanobots made from shiny metal are actually pretty far off still – I'm not sure that route is really going anywhere," says Prof Hendrik Dietz, head of the Laboratory for Biomolecular Nanotechnology in Munich. "We adapt or mimic the methods used to assemble functional molecules in nature. We are looking to do chemistry how our bodies do it, by building enzymes or drug-delivery vehicles that are smarter than current pharmaceutical methods."

DNA, especially, has proven to be the perfect material for scientists looking to build functional objects on a tiny scale. Rather than trying to manufacture components, scientists create a length of DNA with a particular genetic sequence. The way the different subunits of the strand interact with

PHOTOS: SCIENCE PHOTO LIBRARY, GETTY X5, ISTOCK X3

Optical microscope

Unaided eye

Cancer cell

Human hair

40,000 DNA nanobots would fit on this full stop

Baked bean

Tennis ball

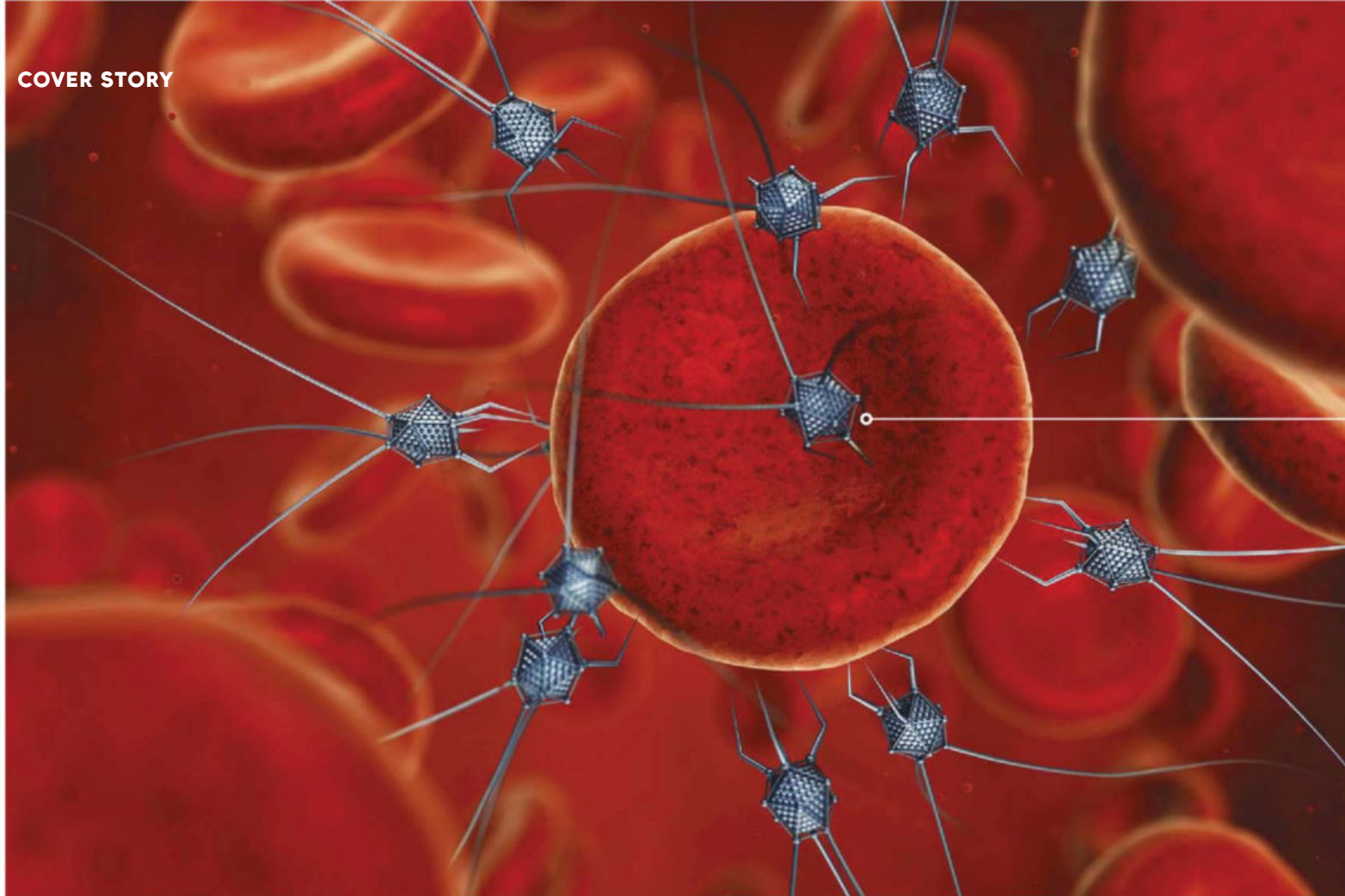
10,000nm

100,000nm

1,000,000nm

10,000,000nm

100,000,000nm



each other causes it to fold itself into highly predictable two- and three-dimensional shapes as it is formed. The longer the lengths of DNA, the more complex the shapes that can be formed.

Manipulating DNA in this way is known as ‘DNA origami’ and has been used to create objects such as tiny walking machines, boxes that open and close, and self-destructing drug-delivery vehicles. It may be some time before this technology is used in the body, but the complexity of DNA-based nanomachines is already impressive. Scientists have even constructed a microscopic alphabet to show their skill in making DNA form any shape.

“No other material can compete with DNA in terms of precision and self-assembly,” says Dietz. “It folds into a precise shape based on the sequence of base pairs we have programmed. These self-assembly methods are much finer than what you can do with traditional ‘top-down’ design.”

Other researchers use entire viruses as the basis for their nanomachines. While viruses are normally thought of as harmful infectious agents, they can also arguably be seen as nature’s nanomachines – perfectly evolved to travel deep into their hosts and inject a genetic payload into cells to infect them. Biologists are increasingly using non-deadly viruses to ‘infect’ human cells with new genes in order to replace those that cause genetic disease. The viruses can be shielded from the body’s immune system by altering their outer casing, and – like lab-built nanoparticles – this outer surface can be modified to ensure they target specific cells.

The nanobots in this illustration look a little like viruses, which in themselves can be used in nanomedicine

The number of potential uses of nanotechnology in medicine is dizzying. As well as tiny devices, scientists have developed gels that self-organise at the nanoscale into structures that can stop bleeding in wounds within seconds. And a team in South Korea has designed a nanobandage – a dressing that contains stretchable, wafer-thin nanotechnology that monitors a patient’s muscle activity or skin condition, then administers medication as needed.

WHAT NEXT?

This seemingly unending potential has led some to suggest that nanomedicine could make humans virtually immortal within a few decades. Renowned futurist Ray Kurzweil has stated that within the next century he believes DNA-based ‘nanobots’ will eventually be a routine part of our blood, scanning each cell in our bodies for damage to repair.


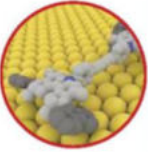


In the shorter term, researchers like Dietz believe that integrating biology-based nanotechnology and traditional engineering could revolutionise the power and efficiency of technology outside of the body too. “The more transistors you can pack into a space, then the more calculations you can do per

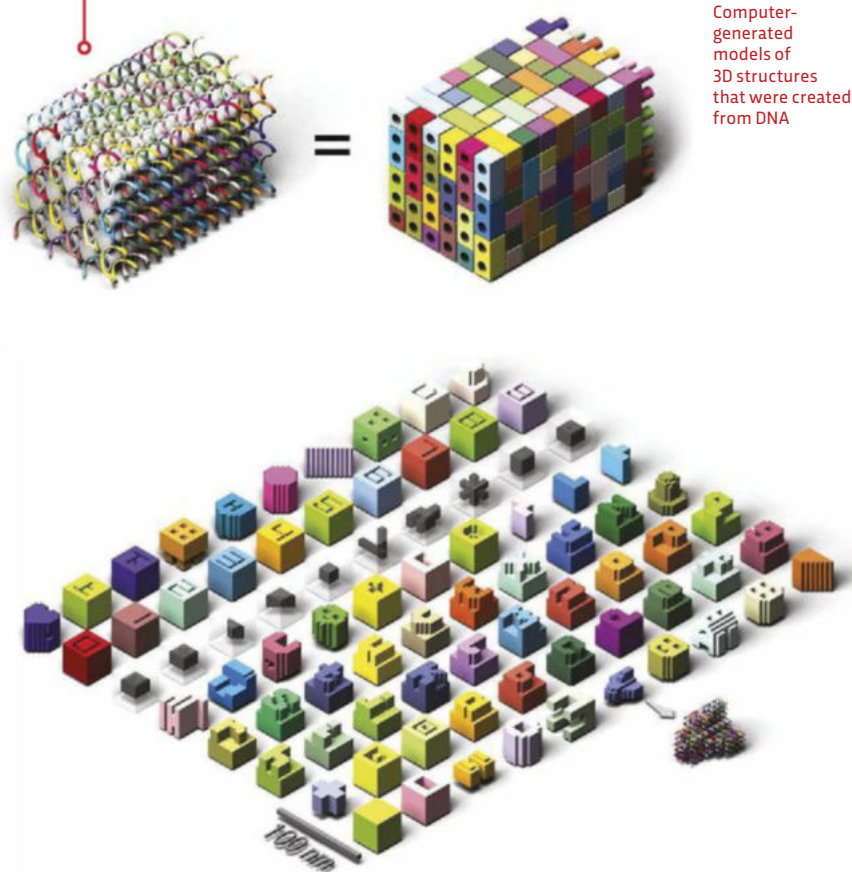
second,” he says. “A combination of super-fine, self-assembling DNA nanostructures and existing technology could help us reach another level of efficiency in computing.”

“Nanomedicines could make humans virtually immortal”

THE DIMINUTIVE DOCTORS

Some of the most intriguing nano devices currently being researched


	Type	How it works	Target	Made from	Benefits
	VIRUS	A virus injects its own genes into its host's cells	Any living organism or cell	DNA and protein	Viruses are already used as nanomachines to deliver replacement genes into cells, including those of humans
	MOLECULAR MOTOR	Chemical reactions make sections of a nanoparticle move, propelling it forward	N/A	Complex chemicals such as amino acids or proteins	They could allow bots to move in a specific direction, or break down fatty deposits and clots
	WORM-SHAPED NANOPARTICLE	Can evade the immune system, which means that the body will not eliminate them	Tumours	Synthetic polymers	Can be made into different shapes for different jobs
	DNA NANOBOT	When this DNA-based device recognises a target cell, its two halves swing open to release a payload	Cancer	DNA	Self-assembles, non-toxic



Computer-generated models of 3D structures that were created from DNA

For now, the goal is to prove nanotechnologies are safe and effective when used in medicine. As nanomedicines stay in the body for longer than traditional drugs, there is a greater risk that they may have lasting unwanted effects. Those containing certain metals are more likely to be toxic should they accumulate in the body. If the remaining hurdles can be overcome, it heralds a new era in smarter treatments that are tailored to function only in particular areas in the body. These targeted treatments have the potential to make traditional medicines, which act on the entire body, seem crude in comparison.

The global nanomedicine market is already estimated at being worth between \$150bn (£104bn) and \$250bn (£173bn), and will only continue to grow as more treatments are licensed for use.

Today's nanomedicines may not look like the submersible in *Innerspace*, but they're arguably far, far smarter. Made from DNA that can build itself and with biological molecules as their navigator, they won't go wrong or get lost. This tiny technology is coming to a human being near you – and soon. 

Tom Ireland is a freelance science writer and also edits *The Biologist* magazine.



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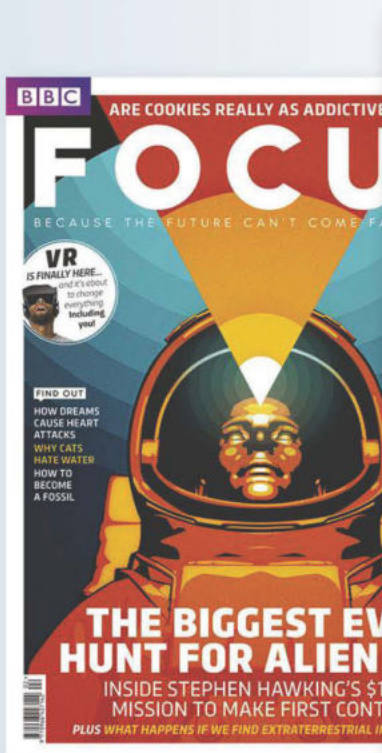
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“PEOPLE SAY: ‘BUT YOU’RE SO OLD. WHY ARE YOU WORKING?’ WELL, I WOULD PAY TO CARRY ON DOING WHAT I’M DOING!”

On the eve of his 90th birthday, **Sir David Attenborough** talks to **Ben Hoare** about his illustrious career as a much-loved broadcaster and conservationist, and spills the beans on his worst ever experience in the natural world

You once said your job involved “swanning around”. On screen you certainly look like you’re having fun...

Having fun is not difficult. It’s one of the few talents I have – enjoying myself. So it’s obvious why you do this – you’re having a ball! People say: “But you’re so old. Why are you working?” Well, I’d pay to carry on doing what I’m doing!

What’s your favourite possession?

The skeleton of a tiny crustacean called *Kiwa tyleri* is my favourite object – it sits on my desk. It was collected from a hydrothermal vent at the bottom of the Atlantic near South Georgia. No human could ever survive alongside this marvellous little thing.

Are there any animals you don’t like?

Rats.

People might picture you in an idyllic Georgian pile in the country, like your heroes Charles Darwin or Gilbert White. Yet you’ve lived in London for years.

I’m a very urban man. London is the most fantastic place if you’re interested in scholarship, learning, music... the greatest libraries in the world are here, the greatest natural history museum in the world is here, the music is unrivalled. But I have it both ways. I can pop off to Borneo for three weeks.

What would your superpower be?

To fly. Not gliding, mind, I want powered flight, please! I don’t just want to float around when the wind is right. I want to be able to just stretch my wings and take off. The nearest you can get to flying is underwater swimming or scuba diving. The ability to move in three

dimensions is what you experience when you are scuba diving. But to do that up in the sky, to be able to take off and have a look at the Cotswolds, would be fantastic.

What has been your worst experience in the natural world?

I can remember being stranded on Mount Roraima in the Venezuelan rainforest – it inspired Conan Doyle’s novel *The Lost World*. We were filming on the summit [for *The Private Life Of Plants*] and we did the sensible thing, which was to go up by helicopter instead of carrying all our stuff. But this place attracts weather: it attracts clouds. And then we found we only had one tent, and there were about eight of us. And it started to rain quite heavily. There was bare rock with water sluicing across it, ●



PHOTO: GETTY

bbc one

David Attenborough
will be presenting
Planet Earth II on
BBC One later this year.
Check the *Radio Times*
for more details.

and we all just sat in the tent on top of one another. I remember that night very well – the torrential rain and that tiny two-man tent with all eight of us in it. At least we got the sequence. But the question is: did they use it? And the answer is no!

What extinct creature would you most like to meet?

Quetzalcoatlus. It was a pterosaur – a contemporary of the dinosaurs but with wings the size of an aeroplane. We make programmes about it, but the truth is we still don't really know how it took off. I personally think it was a scavenger. It had a very curious neck where the vertebrae locked and became like a long rigid pole, with its long jaws at the end of it. And I think that was in order to get inside a *Brontosaurus*. If you look at vultures now, with their long, bare-headed necks, which they push into carcasses to pull out the guts... well, if you are going to pull the guts out of a titanosaur you have to be pretty damn big. So that's what I think the long neck was for.

What keeps you up at night?

Sitting up and reading, that's what keeps me up... we're in a golden age of science and nature publishing.

WORK AND ACHIEVEMENTS

Do you watch your programmes when they are broadcast?

Not really. By the time they go out, if you've not already watched them 50 times then you've not done your job properly. But I do watch other people's natural history programmes. You've got to watch them... what other people are doing is the interesting thing.

You always emphasise the amount of teamwork involved...

By golly, you need to make it clear that you have very little to do with getting those fantastic shots. Twenty-five camerapeople working for three years – how can you tell people you did all that yourself?

What are you working on at the moment?

A programme about bioluminescence. It's such a romantic subject. Glowworms in the British countryside? American woods full of fireflies? Amazing! Do you know that there are luminous

“You can look at all the films you like of elephants, but until you've seen one shifting and creaking as it moves around, you don't understand how big it is”



Sir David holding an armadillo in 1963 for an episode of children's series *Attenborough And Animals*

earthworms? They look a lot like the worms you get in the garden, but if you dig a hole to find them, they're glowing. There's nothing attacking or frightening them. The earthworms themselves can't see. So what on Earth is going on? Possibly it's a by-product of physiological processes, such as waste disposal or something of that sort.

The David Attenborough Building (the new conservation campus at the University of Cambridge) opened in March. You must be proud!

It's a funny business, having buildings named after you. But this offer was irresistible... Cambridge is the place where I first saw the diversity of the world. In biology at school I learned that there is a crayfish and a dogfish and a cockroach and a rabbit, and that was about it. Then when I came to Cambridge as a student in 1945, my eyes were opened. I remember one lecture on amphibians, focusing on the breeding strategies of frogs. I suddenly went: "Wow!" The adaptive radiation of frogs was just astounding.

Some people criticise the BBC and question its purpose. What's your view?

In the end, it's about programme policy. If I was a shareholder in ITV, then I would want a decent return. Being interested in ratings is fair enough – it's what ITV is there for. But that's not what the BBC is there for.

THE NATURAL WORLD, SCIENCE AND THE BIGGER PICTURE

Are you optimistic about what the conservation campus at the University of Cambridge can achieve, in the face of overwhelming biodiversity loss?

Of course, you have to be. It is going to bring together all of these people concerned about the natural world – the biologists, the conservationists, the charities. Other disciplines will be represented too, such as sociologists and anthropologists. So it's a huge melting pot. Wonderful things will happen.

Can we learn anything from animals?

I'm suspicious of this... why do you want to learn from them? I'm not interested in how like us they are, but in how *unlike* us they are. I mean, we've all got the same problems – finding mates



Plunging beneath the waves in 1990's *The Trials Of Life*

and homes and rearing the kids and one thing or another. It seems to me that if you have to beat the drum to say it's interesting how a spider copulates or how a male spider placates its mate to prevent itself being eaten... if you aren't interested in that, then I give up really.

What role do zoos have nowadays?

There are three very clear functions for zoos. One is to let people, young and old, see the reality of an elephant. You can look at all the films you like of elephants, but until you've actually seen one shifting and creaking as it moves around, you don't understand how big it is. It would be terrible if people only saw television pictures of elephants and nothing else. The second thing is that you learn a lot about the natural world if you keep your animals in an intelligent way. And the third thing is that zoos can be a last-ditch defence against extinction. But having said that, you assume they are properly run zoos. And the rule of thumb as to whether or not you are keeping an animal satisfactorily is whether or not you are managing to breed it.

Rewilding is a movement that aims to return lost species to Britain, such as beavers, lynx and wolves. Are you a fan?

We have got a hell of lot of problems even keeping alive what is already surviving here. Admittedly, putting beavers back [in the wild] seems relatively innocuous. But I just feel that we've got enough on our plate as it is.

Do natural history museums – and all their neatly catalogued collections of preserved specimens – still have a role?

Let's not denigrate taxonomy; taxonomy is like learning the alphabet. You can't speak English properly unless you've got definitions, and you can't do zoology properly unless you know all about the

LIFE ON AIR

1926 – Born David Frederick Attenborough on 8 May.

1933 – Builds collection of fossils and stones, kick-starting a love of nature.

1947 – Achieves natural sciences degree at Cambridge University.

1952 – Joins fledgling BBC.

1954 – Brought into the public eye as the presenter on *Zoo Quest*.

1965 – Made controller of BBC Two and oversees introduction of colour television to the UK.

1969 – Becomes responsible for both BBC One and BBC Two.

1973 – Resigns his post to concentrate on making documentaries.

1977 – *Wildlife On One* first broadcast. Runs for 33 seasons.

1979 – *Life On Earth*. Watched by around 500 million people worldwide.

1985 – Awarded knighthood.

1995 – *The Private Life Of Plants*. Boasts new time-lapse photography.

2005 – *Life In The Undergrowth*. Uses cutting-edge macro photography.

2006 – *Planet Earth*. The most expensive wildlife series ever made and the first to be shot in HD.

2010 – *Flying Monsters 3D*. The UK's first 3D documentary.

2011 – Presents *Frozen Planet* and becomes oldest person to set foot on the North Pole at the time of filming.

2016 – *Planet Earth II*. Entirely filmed in 4K, it includes the use of drones and the image stabilisation techniques.

structure and relationships of the animals you're discussing.

How has zoology changed in your life?

In my time as a student, academic zoology was very lab-bound. The professor of zoology was an expert on animal locomotion but he didn't observe it outside – he'd get an animal and put it on a treadmill in a laboratory. Field zoology, or being a naturalist, was until recently quite separate from academia.

What is the biggest ecological change you've seen in your lifetime?

Human beings. The world population has tripled since I started making programmes in the 1950s. Tripled! In no time at all... so now wherever you go, you see human beings and the consequences of what human beings have done. That's the huge change.

How can we deal with ballooning energy consumption?

I support the Global Apollo Programme. It is called that to make the point that if people can put a man on the Moon in 10 years, why shouldn't they be equally determined in developing a way of collecting, gathering and storing one-500th of the amount of energy that the Sun sprays on the Earth every day? If you did that, you would deal with all our power requirements.

Can we do it?

The situation is unprecedented. In the entire 200,000-year history of the human race, the whole population has never come together before. We've always been fighting our own corner. Now we have to say: "Okay, there is only one way out of this. We are all in the same boat."

Speaking of space exploration, should we be trying to colonise other planets?

No, of course not! You mean go and make a mess of them too? We don't know of anywhere where human beings can remain like human beings. They can be like bottled specimens, tied up in their own mini atmospheres, plodding about, but that's all. 🌍

Ben Hoare is the features editor of *BBC Wildlife*.

DISCOVER MORE

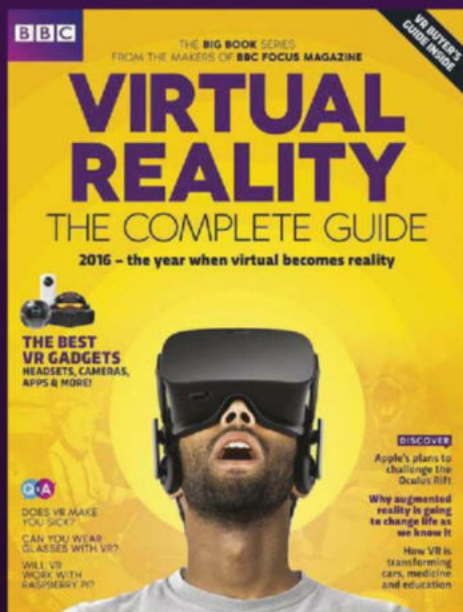


Inspiring Attenborough: Sir David At 90 airs on BBC One on 8 May.

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ROBIN INCE ON... **CANNIBALISM**

“CANNIBALISM HAS ALL BUT DIED OUT. THERE IS SCANT MENTION OF IT ON TV COOKERY SHOWS”



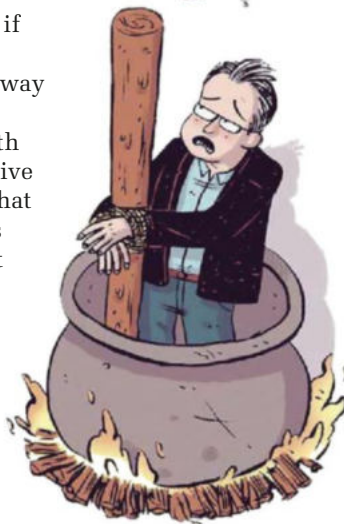
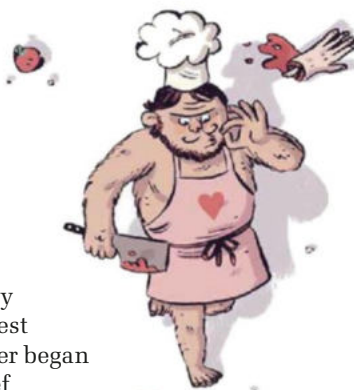
here is a lot of negativity towards cannibalism. In the 21st Century, it

seems to have all but died out. There is scant mention of it on TV cookery programmes, either as a totemistic or nutritional diet choice. By clumsy chance, as I write this, I am sucking blood – my own – having gashed open my finger while rummaging for my laptop in my rucksack.

Several years back, there was the gory news story of a German man who advertised for someone who would volunteer to be eaten. I'm not sure which magazines accept classifieds from hungry human flesh-eaters – these are the loneliest hearts columns. Apparently, the volunteer began to experience regret when he and the chef partook of his flesh together. I don't know if this was an issue over seasoning, or the realisation that this was a less glamorous way to die than he'd imagined.

It was while I was in Germany last month that my thoughts turned to the more positive sides of cannibalism. In Leipzig, I learnt that cannibalism can be a boon for the curious evolutionary geneticist. Swedish scientist Svante Pääbo is one of the founders of palaeogenetics. He led the team that sequenced the Neanderthal genome in 2010, which provided new evidence for interbreeding between Neanderthals and modern humans. Headlines appeared when suppositions were made that our genetic inheritance from the Neanderthals included allergies, incontinence and depression, but also our ability to fight disease.

But what has all this got to do with cannibalism? One of the major problems of sequencing the DNA of extinct creatures, or any elderly relic, is the degradation that



occurs over time. It is hard to find specimens untainted by bacteria, human touch or the multitude of other ways in which nature can maul a bone.

In 1994, however, a large cache of Neanderthal bones was discovered in the El Sidrón cave in northern Spain. The bones had scars and cut marks across them, suggesting that they'd been sliced to remove flesh and muscle for the purposes of a meal. The archaeologists think that this particular family were victims of survival cannibalism, which means they were eaten out of necessity rather than desire (dietary cannibalism) or for mystical reasons (symbolic cannibalism).

This terrible act of survival has given modern geneticists a great advantage. As the bones were lacking in tasty sinews, they were far less appealing to bacteria, wild dogs or anything else that might have scavenged, trampled or eroded them. All these things would have further damaged the integrity of the Neanderthal DNA.

So the bone samples found themselves taken from a cave of death and destruction to the remarkably clean basement of the Max Planck Institute for Evolutionary Anthropology, where among Tupperware and UV light, Pääbo and his team now search for the holy grail of DNA. Within some of these pecked and sucked at bones will be gene sequences that reveal more about the effects of the coupling between Neanderthals and our *Homo sapiens* ancestors.

In 17th-Century Europe, human remains were often used as ingredients in medicine. Charles II's tincture, 'the King's Drops', for instance, contained distilled human skull and was used to treat a variety of ailments.

Unfortunately, snacking on human remains didn't do much for Charles and co. But the sad necessity of cannibalism 40,000 years ago is helping us to discover why we are who we are.

With new genetic sequences, we may make new medical breakthroughs – without the need to munch on a still-beating heart. 🍌

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.
NEXT ISSUE: BIOENGINEERING



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OUR FUTURE

RICH IN RESOURCES AND FUEL, THIS PLANET COULD BECOME OUR TICKET OUT OF THE SOLAR SYSTEM

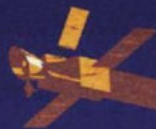
WORDS: STEPHEN BAXTER ILLUSTRATOR: MAGIC TORCH

ON MERCURY

On 9 May 2016, Mercury will pass between the Sun and Earth – the first transit in 10 years. And in 2017, the Japanese and European space agencies will be launching BepiColombo – the third ever space probe to visit Mercury.

Space visionaries contemplate Mercury with an eye on the future

because the resource-rich world is close to the Sun and all of its energy. We asked Stephen Baxter, renowned science-fiction writer and member of the British Interplanetary Society, to envision how Mercury could be the stepping stone to exploring the Solar System and beyond. ●



STAGE 1

SETTING UP A BASE

Mercury, the innermost planet in our Solar System, was once an enigma. For years, its proximity to the Sun made it difficult for astronomers to observe – but the space age changed all that. NASA's Messenger, the second space probe to Mercury and the first orbiter, was launched in 2004 and orbited the planet from 2011 to 2015. The data it returned gave us real knowledge about Mercury for the first time.

PECULIAR PLANET

Mercury takes 88 Earth days to orbit the Sun, and rotates once on its axis every 59 Earth days. It was not until the 1960s that even these basic facts were established. But standing in any one place on Mercury, you don't see the Sun rise every 59 Earth days because of that short year. Mercury is so close to the Sun that tidal forces have locked in its rotation periods: three Mercury 'days' are the same as two Mercury 'years'. The net effect is that at any point on Mercury's surface you will only see a sunrise every 176 Earth days.

If you were to stand on Mercury, superficially it might seem like the Moon: a small, airless world with a rocky surface distorted by huge, ancient craters. But the details vary, because of the planet's different location and composition. On Mercury, there are peculiar linear features called rupes (Latin for 'cliffs') that resemble wrinkles on a

shrivelled apple – and it's thought that is pretty much how the rupes formed, with the planet shrinking by a kilometre or so as it cooled.

And Mercury's gravity might surprise you. Though the planet is only a little larger than the Moon, its gravity is about twice as high. Mercury was once a more massive world with, like Earth, an iron core and a rocky mantle. An immense collision with another young world may have stripped off much of that mantle, leaving the planet with an outsize core and a higher density to match.

If you could stand on Mercury, the Sun would look twice the size in the sky as it does from Earth – and there would be barely a scrap of atmosphere to shelter you, or to retain the heat in the night. At 'noon' the ground is hot enough for lead to melt; at 'midnight' the temperature plummets to nearly -200°C. Even the Messenger craft had to be designed to take these challenges into account. "The front side of the sunshade routinely experienced temperatures in excess of 300°C," explains Helene Winters, mission project manager. "Whereas the majority of components in its shadow routinely operated near room temperature".

You might think it will forever be impossible to live on Mercury. But nature, uncharacteristically, may have given future explorers a break. The planet has no axial tilt, so there

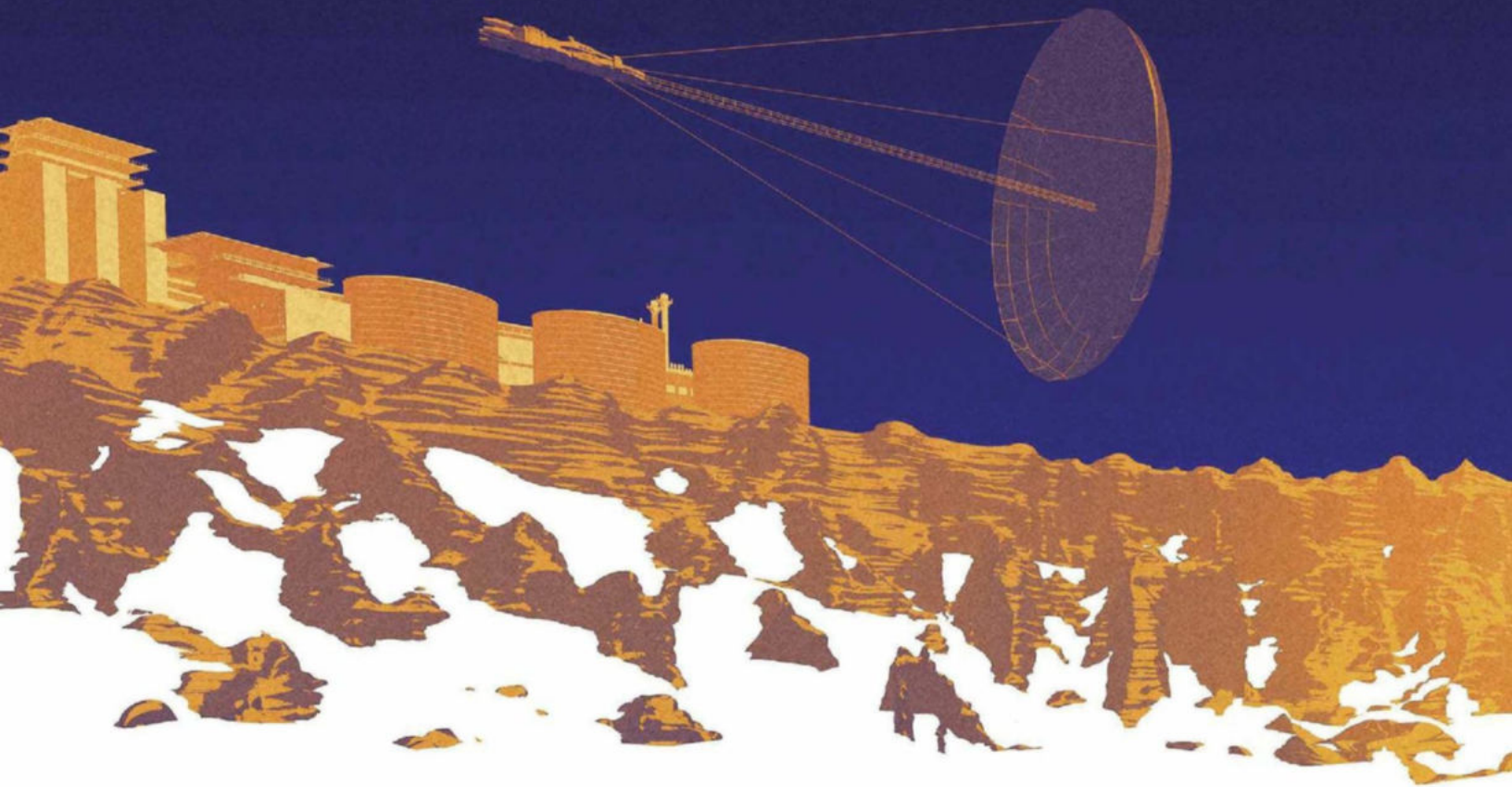
are no seasons. This means that at the planet's poles, there may be craters where the Sun never shines. And there lies a miracle, discovered by Messenger: water ice, delivered by the impacts of comets and frozen in the permanent shadows – life



support for future colonists. But aside from science exploration and perhaps some pretty extreme tourism, why would we ever want to go to Mercury?

In fact, Mercury could be one of the Solar System's most strategically valuable locations... ●

An artist's impression of our arrival at Mercury. In reality, the chosen location would be in constant darkness



EARTH

DISTANCE FROM SUN

152,100,000km (at furthest point)

MASS

5.97×10^{24} kg

RADIUS

6,378km

DENSITY

5,514kg/m³

GRAVITY

9.8m/s²

YEAR

365.25 Earth days

DAY

24 hours

DAY-NIGHT CYCLE

1 Earth day

DAY TEMPERATURE

57°C (max)

NIGHT TEMPERATURE

-89°C (min)

SOLAR POWER RECEIVED PER M²

1,361 Watts



MERCURY

DISTANCE FROM SUN

69,816,900km (at furthest point)

MASS

0.33×10^{24} kg

RADIUS

2,440km

DENSITY

5,427kg/m³

GRAVITY

3.7m/s²

YEAR

88 Earth days

DAY

59 Earth days

DAY-NIGHT CYCLE

176 Earth days

DAY TEMPERATURE

427°C (max)

NIGHT TEMPERATURE

-173°C (min)

SOLAR POWER RECEIVED PER M²

9,083 Watts



STAGE 2

BUILDING A SPACE PORT

It might seem odd, but Mercury may be a good site to mine. If we move off the Earth, a growing interplanetary civilisation is going to need resources, in terms of materials and energy – and Mercury has energy aplenty in the form of that concentrated sunlight. To capture as much energy as a square metre of solar-energy cells on Mercury would require six square metres on the Earth – and 60 square metres at Ceres, a dwarf planet that's often touted as a good candidate for resource extraction.

RICH RESOURCES

As for the resources, there is strong concern about the impact of mining on Earth, in terms of environmental cost; plus, resources extracted from Earth would be expensive to lift into space. So it would be far better to mine out there. That prospect may be coming closer, with the emergence of the Alliance for Space Development, led by the US's National Space Society, to press for legislation and initiatives to allow development of space resources.

But where to mine? A first obvious choice is the Moon. While the Moon is deficient in volatiles like water, its surface is full of useful components such as oxygen, calcium, magnesium, potassium, even heavy metals like titanium and aluminium. Mercury's mantle has much the same composition, and so techniques developed on the Moon could easily be transferred there. In addition, the huge amount of solar energy received by Mercury could be used to drive the mining operations themselves, and for firing packets of resources to sites across the Solar System – perhaps using 'mass drivers'. These electromagnetic slingshots were first suggested by Arthur C Clarke. It might be more acceptable to mine remote Mercury than to scar Earth's Moon, plus Mercury's huge core – mostly iron, but rich in other metals – is only 600km down in some places, whereas the Moon's smaller core may be up to 1,400km down.

There are still more imaginative schemes. All that sunlight could be used as a free propulsion system.

Imagine a solar sail, strong but thin, perhaps built out of Mercury's aluminium. When sunlight hits a reflecting surface, it exerts a pressure – as if the particles of light are rebounding from the surface and pushing it away. The effect is small, but it's useful, continuous and free. At the distance of Earth, a sail measuring 800m across would receive a light-pressure of about five newtons, which is similar to the thrust of the low-drive ion-propulsion engines used on NASA's Dawn spacecraft. And the closer you get to the Sun, the greater the thrust – at Mercury you would get the same thrust with a sail measuring less than half that diameter. If you wished to ride a solar sail to Neptune, the most distant planet, it would be better to pay a visit to Mercury first to pick up the greater acceleration, and then sail outwards.

Mercury may some day become the shipyard and principal port of the Solar System. And looking even further into the future, there are still bolder suggestions. ●

STAGE 3

TERRAFORMING

In his 1984 novel *The Flight Of The Dragonfly*, physicist and science-fiction writer Robert Forward suggested a solar-sail starship, to be built at and launched from Mercury: “a Solar-System-wide machine that would toss [the crew] to the stars on a beam of light”. At the core of Forward’s propulsion system is a set of 1,000 laser stations, each 30km wide, in orbit around Mercury. These together capture solar energy into laser beams with a combined total power of 1300TW, equivalent to about 1 per cent of all the sunlight intercepted by Earth, and blasted at a sail a thousand kilometres across.

But Mercury’s future may hold greater miracles yet. Could we turn it into a second Earth?


Terraforming, the art of turning an uninhabitable world into a habitable copy of Earth, is usually considered in the context of Mars. Mars has a similar orbit to Earth’s, a similar length of day, and at least some of the necessities for life in water and carbon. But Mercury does have some natural advantages, even over Mars. That relatively strong gravity would enable it to hold on to at least some of an imported atmosphere. And Mercury has a comparatively strong magnetic field – less than Earth’s, but stronger than that of Mars or Venus, perhaps a product of its huge iron core. Just as on Earth, such a field would help deflect harmful solar radiation from the planet’s surface.

Otherwise, though, the challenge of turning Mercury’s liquid-lead, hard-vacuum surface into a shirtsleeve environment seems enormous. To emulate a sunny day on Earth, the incident sunlight would have to be reduced by some

84 per cent. Perhaps this could be achieved with a huge deflecting mirror – a sunscreen the size of Mercury itself. Mercury lacks water and other volatiles; even the polar deposits would be a minor scrape in this context. The dismantling of a small moon of Saturn, perhaps 300km across, could supply this need. Even then, imported terrestrial life would suffer from Mercury’s enormously long day-night cycle. Perhaps this could be jury-rigged using orbiting shields and mirrors.

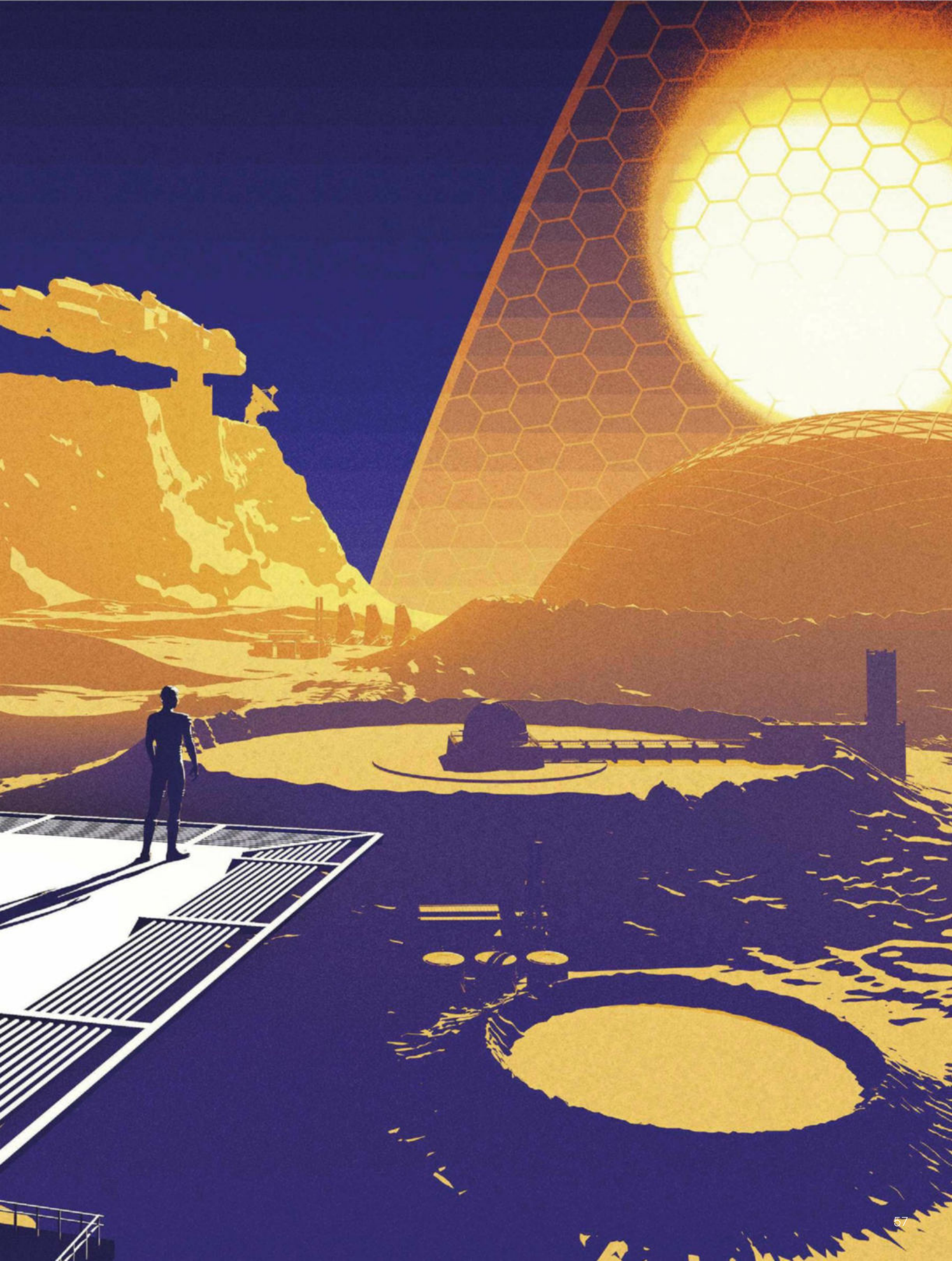
IN A SPIN

A more permanent but trickier solution might be to spin up the planet, so that it rotates more quickly. And in the same spirit, the sunlight issue could be solved simply by dragging the planet further from the Sun. Such schemes have been considered in sci-fi literature, by shooting massive objects – the fragments of moons perhaps – past the planet to use their gravitational fields to spin or drag it. A much more advanced culture than ours may have better ideas in the future.

Mercury, a Moon-like world spinning close to the Sun, seems a dismal candidate for terraforming. But such is Mercury’s potential wealth in minerals and energy, and such is the pivotal role it may one day play in the development of an interplanetary, or even interstellar civilisation, that perhaps such a project will be considered by a future society inconceivably richer and more powerful than our own. 

Stephen Baxter is a prolific sci-fi author and member of the British Interplanetary Society.





WHERE NEXT FOR WEARABLES?

More than one in five of us now own a piece of wearable tech, but most devices can't do much more than tell us how fit we are. We asked the editor of Wareable to convince us otherwise... Words: Michael Sawh

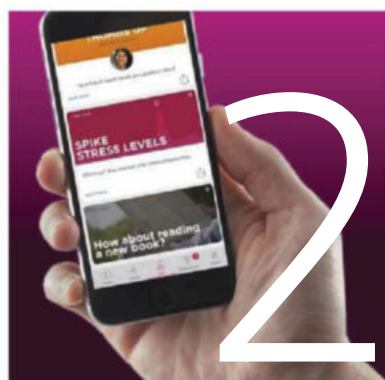
1 A necklace that listens to what you eat

Counting calories is one of the biggest challenges facing fitness trackers. Most wearables ask you to log your breakfast by picking food out of a vast database, and by the time you've found your specific meal it's probably time for lunch. But now a team of researchers in China think they might have solved the problem, with a necklace that recognises food by the way it sounds when it's being eaten.

The AutoDietary smart necklace houses a high-fidelity microphone which, when you start to eat, records the noises, sends the information wirelessly to a smartphone and matches it against a database of sounds that foods make when we bite, grind and swallow them. It sounds highly ambitious, but the team has had

promising results. Using a collection of different foods including apples, carrots, peanuts and cookies, the necklace registered an 85 per cent success rate. But it struggles to recognise some foods, like soup, so to identify these items, an additional device may be required that measures factors such as blood sugar levels.

If the team can pull it off, the necklace could do more than simply help keep a closer eye on calorie intake and break down our consumption of unhealthy stuff like fat and sugar. It could have real benefits for diabetes sufferers or go some way to prevent bowel disorders and other debilitating food-related ailments.



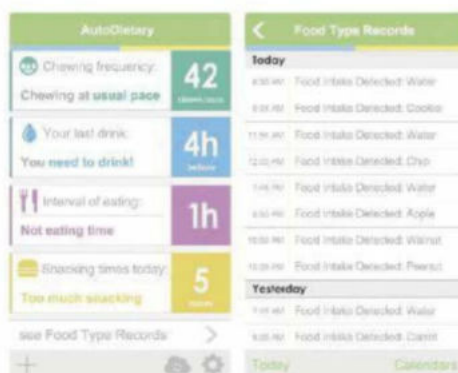
2 Wristbands that track stress levels

Most of us have a notion of how fit or unfit we are. Stress, on the other hand, is a more slippery concept. It's far harder to know how much stress is unhealthy and what

steps to take to reduce it. So US start-up Sentio is working on a wristband that aims to reliably measure your stress. The Feel promises to track human emotions during the day and hopefully get you back to a calmer state.

The sensor-packed wristband will record a host of data including motion, pulse, skin temperature and electrical properties of the skin. When those sensors are combined, they'll help to detect your Electrodermal Response (EDR), a key indicator of your emotional state.

That data can then be sent in real time to the Feel smartphone app, where you can check in on your current emotional state and piece together the factors that cause stress. A vibrating alert will give you a nudge when you've entered a particularly stressful moment and the app will offer calming advice. It will suggest breathing and meditation exercises to get you feeling good again, while a personalised wellness program will suggest better habits, set goals and track your progress to help you make long-term, worthwhile lifestyle changes.



The AutoDietary smart necklace is still in its early stages of development, but the team behind it hope it could bring tangible health benefits to people suffering from complaints of the digestive system



The Quell is strapped on just below the knee

Quell promises pain relief at the touch of a button, but doctors stress that it's only an interim solution



3 A knee strap that will tackle pain

Quell is a wearable that hopes to tackle one of the toughest problems in medicine, chronic pain, without drugs. The sport band is worn around the upper calf and uses an electrode to stimulate sensory nerves in the calf. It's a treatment known as TENS (transcutaneous electrical nerve stimulation), which reduces the pain signals being sent from your muscles to your spinal cord and

brain. It's even thought it may help to stimulate the brain's production of endorphins – the body's natural painkillers – but the jury's still out on that.

The treatment provides short-term pain relief, and helps patients avoid over-reliance on drugs. An app lets you control the strength level, but the NHS advises that this kind of approach isn't a long-term solution.

4 A contact lens that can help prevent blindness

Glaucoma is one of the leading causes of blindness, with an estimated half a million people affected in the UK. The condition has no symptoms until it's well established, meaning that it can rob patients of their vision before it's diagnosed. This soft, silicone contact lens from Sensimed – which has been given the thumbs-up by the US Food and Drug Administration – is designed to detect glaucoma far earlier than any current test. It uses a built-in microsensor to measure the pressure levels in the fluid in your eye, known as the aqueous humour. In glaucoma cases, this fluid pushes against the optic nerve, and over time causes damage. Crucially, this contact lens can be worn for up to 24 hours, tracking the pressure levels continually – particularly at night, when lying on your back can increase the pressure on your optic nerve – whereas a standard eye test will only take one reading. This simple diagnostic test could save the vision of hundreds of thousands of people.

Sensimed aren't the only ones at it, either: Google has been working on a similar lens to help diabetics monitor their glucose levels.

Sensimed's contact lens monitors pressure in the eye, enabling doctors to diagnose glaucoma earlier



5

A mask that will help you look beautiful

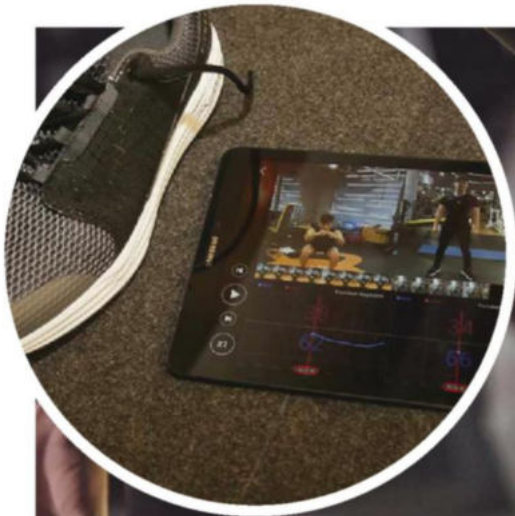
Meet Mapo, the connected facewear that wants to keep you looking beautiful. This custom 3D-printed silicone mask, designed by French company Wired Beauty, uses a series of sensors that can detect the skin's moisture levels at different points on your face.

Data from your scans is then sent wirelessly to a companion smartphone app, where it'll offer advice to address your particular

skin issues, such as suggesting what type of skincare products you should be using. This can also be charted against details of your daily routine and those of other users, to try and draw on the wisdom of the crowd to source the most suitable treatments for your skin.

A series of heating zones positioned in key areas around the face will also, it's claimed, help to improve the effectiveness of any skin care products applied.

Mapo is a 3D-printed face mask that monitors moisture levels in your skin



6 Shoes that stop you getting injured

A pair of shoes that track your running route might sound appealing, but it's nothing you can't do with a smartphone. lofit, a set of connected footwear developed by a Samsung spin-off, wants to do something different.

The lofits track your balance using a suite of sensors that measure pressure on different parts of the foot. Using this data they will track weight shift, centre of gravity, ground contact force and tempo. In other words, they'll help runners check that their gait, and the way their feet strike the ground in particular, isn't damaging their bodies.

Balance isn't just important for runners, though. The shoes' developers are calibrating the lofit to offer advice to weight trainers, tennis players, golfers and more. And once the shoes have collected enough data on you, the connected app will offer tailored coaching videos to help adjust your balance. The shoes will need charging wirelessly via a mat once a week, and since all the electronics are housed in the outer sole, they can even be thrown in the washing machine.

lofit's shoes record information on foot alignment and other things that serious runners think about when they think about running

7

Pills that measure your performance

Forget wearables, the next generation for tracking tech will be wearing us! 'Ingestibles' will come in pill form, and will be able to monitor us from the inside.

The e-Celsius electronic pill, created by French company BodyCap, looks like a standard paracetamol but comes packed with a temperature sensor, batteries and memory, all wrapped up in a biomedical PVC shell. Once swallowed, it sends data on body temperature, via its radio frequency antenna, to a monitor plugged into your computer every 30 seconds. Data can also be stored on the pill for up to 16 hours. There's no Bluetooth transmitter here, so it can't send information to a smartphone.

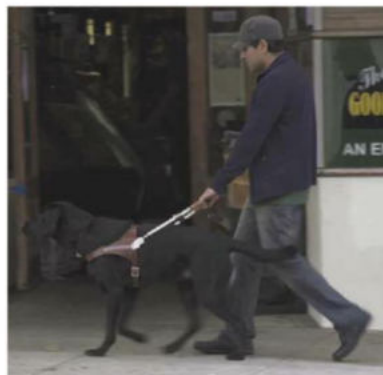
Is this useful? There are a few scenarios where it would be: in a hospital, for example, doctors can identify peaks of fever after surgery or during chemotherapy. e-Celsius Performance pills, though, are designed for elite athletes. They'll be able to record their temperature reliably while training or competing, in order to see the effects of working out in extreme environments.

The smart pill has already been trialled by French football team FC Nantes and by cyclists in the 2015 Road World Championship. But it's just the start of what ingestibles could be capable of: next, they'll be detecting diseases and tapping into our physiological makeup (see p34).

The eCelsius pill sends data wirelessly to an external monitor



Developed in France, eCelsius has already been trialled by leading sportspeople worldwide



The Blaid collar can be worn quite unobtrusively

8 A collar that could help the blind to 'see'

Toyota has spent the last four years collaborating with the blind and visually impaired to develop a wearable that will help them visualise their indoor surroundings. It's aiming to fill the void left when you cannot rely on a guide dog, cane or GPS device.

Project Blaid wants to make it easier for blind people to navigate areas like airports and shopping

centres using a horseshoe-shaped device worn on shoulders. Packed with cameras, speakers and haptic motors, Blaid can interact with the user through voice recognition and vibration, while its vision system is gleaned from current automotive advances such as lane departure alert systems. The device will eventually be able to map locations by identifying visual landmarks such as escalators, signs, and shop fronts, and it will use facial recognition to help identify individuals. Toyota is currently preparing the device for beta testing.

While we might be some time away from seeing the masses making use of Blaid, Toyota believes the wearable innovation could even have a part to play in self-driving cars and robotics. It would appear that the company has clear intentions to offer a helping hand to people from all walks of life, with all sorts of different needs. 🗣️

Michael Sawh is editor of *Wareable*, an online magazine about wearable technology. Find them at wareable.com

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BBC **HiSTORY**
MAGAZINE

BUSTING THE MYTHS OF MODERN LIFE...

Do mice really love cheese? Does sugar make kids hyperactive? Do you actually need your five-a-day? We put 29 common beliefs under the microscope to sort the fact from the fantasy

WORDS: TOBIAS JOLLY

ILLUSTRATIONS: JAMES OLSTEIN

A penny dropped from the top of the Eiffel Tower could kill someone

The building used as the basis of this myth varies. Much more constant is the terminal velocity of a penny, which is around 44km/h (27mph). The penny reaches that speed after it has been falling for about 15 metres (50 feet). Once the penny has reached its terminal velocity, it will not accelerate any further.

Physicist Louis Bloomfield at the University of Virginia used this calculation to replicate the fall of pennies from tall buildings. He found that pennies at that speed would not break the skin – at most, they would just sting a little. ●



Goldfish only have a three-second memory

The life of a goldfish isn't always filled with joys that are worth remembering: countless numbers of these small fish have little to look back on other than a short trip in a tiny bag before being flushed down a toilet. But goldfish do have a better memory than just three seconds – much better in fact. Goldfish can remember the route to take in a simple maze, for example. A study by researchers at the University of Seville also suggested that the fish are able to develop and remember a mental picture of their environment. In the maze experiment, the fish could find their way to a goal from a start point other than the one from which they were trained.

Local honey cures hay fever

Tablets containing pollen are somewhat effective at combating hay fever. Since some honey contains pollen, honey as a hay fever remedy seems plausible. But most honey contains little or no pollen. Even unfiltered local honey has no apparent impact on hay fever.

Bumblebees defy physics

They are big and fat with seemingly tiny wings, making their flight seem improbable. But since science is updated when there is new evidence, if a bumblebee's flight really couldn't be explained by current models then the physics would change. In reality, the insects do not defy any laws of nature. Those wings do indeed provide enough lift to hold up the entirety of a bumblebee's 0.2g.





Houseflies only live for 24 hours

It may seem unfortunate that the annoying housefly lives for more than a day. They can actually live for several weeks. The 24-hour myth probably comes from confusion with the mayfly, of which many species do have incredibly short lifespans in their adult stage. Part of the reason mayflies can get away with such a short lifespan, while still being able to find a mate, is that they swarm. Since a swarm of houseflies might be more of a nuisance than the odd one buzzing round your kitchen, we should probably be thankful that they do not share the mayfly's lifecycle.

Turning the thermostat up high will increase the rate of heating

Unlike humans, who might meet an ambitious challenge by working harder, heating systems don't put more effort in when they have further to go. Setting your thermostat to 30°C will only change the target temperature, not the heating speed. A higher setting will just risk wasting energy while getting you too hot.



You need to drink eight glasses of water a day

Being dehydrated isn't great for your health, but the idea that we need to drink eight glasses (around two litres) of water in order to stay hydrated has no real scientific backing. Research suggests that health can be maintained with a much lower water intake.

As concluded by Dr Heinz Valtin from Dartmouth Medical School, there's also no evidence to specifically drink plain water. You can stay hydrated with any other fluids and the water that's found in most food.

Mice love cheese

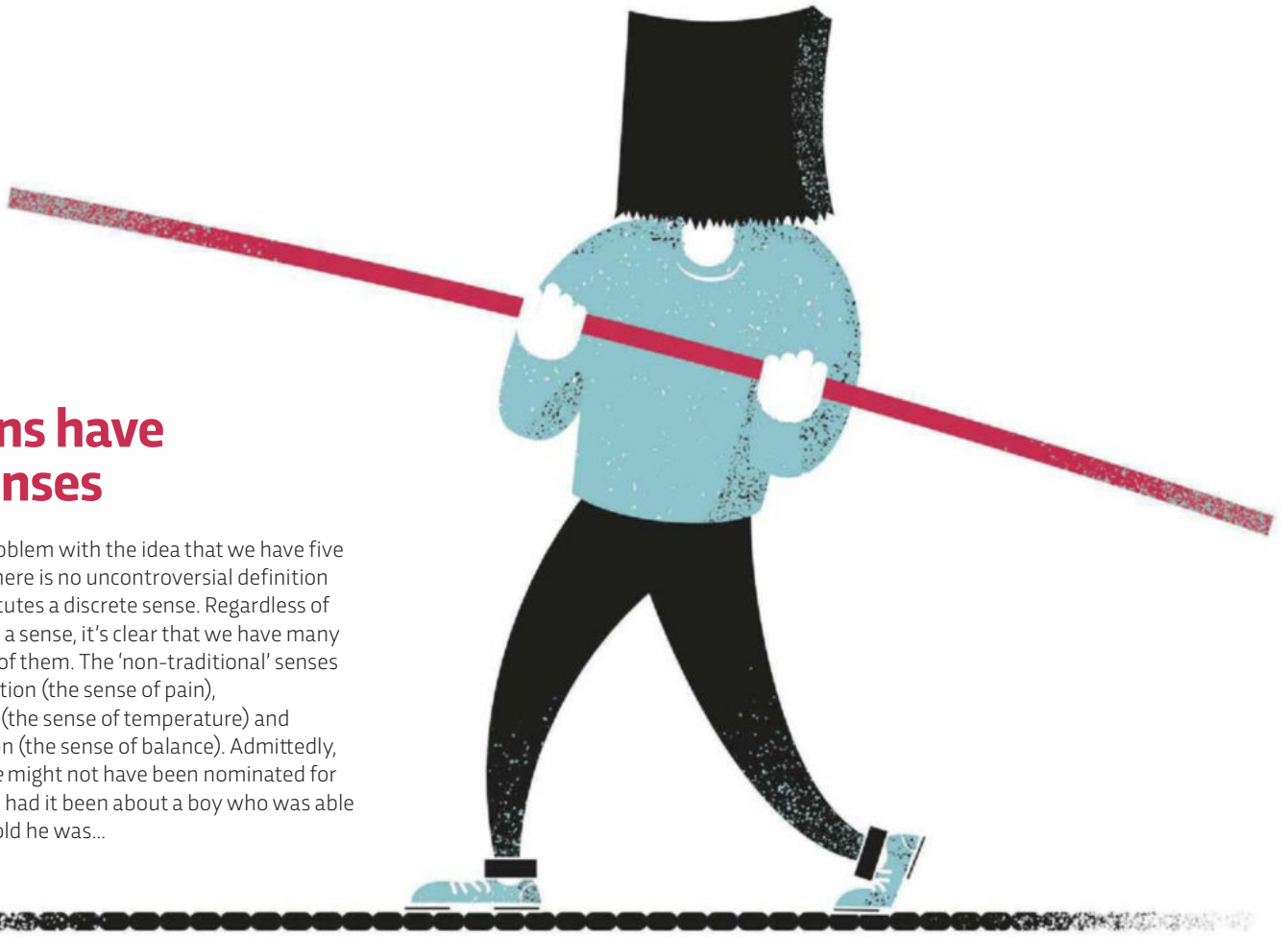
You're not alone if you feel a sense of disillusionment after learning that your childhood cartoons were misleading you. Scientists from the University of Birmingham have confirmed earlier research by showing that wild-caught mice do not appear to have any apparent preference for cheese, and probably prefer seeds and grains. Crunchy peanut butter, another common mouse bait, was also not preferred (perhaps they prefer smooth).

Given that adult mammals tend to have little of the enzyme lactase, required for lactose digestion, cheese probably isn't great for a mouse's health, either. Plus, feeding cheese to a mouse is a criminal waste of cheese! 🐭



Humans have five senses

A significant problem with the idea that we have five senses is that there is no uncontroversial definition for what constitutes a discrete sense. Regardless of how you define a sense, it's clear that we have many more than five of them. The 'non-traditional' senses include nociception (the sense of pain), thermoception (the sense of temperature) and equilibrioception (the sense of balance). Admittedly, *The Sixth Sense* might not have been nominated for as many Oscars had it been about a boy who was able to sense how cold he was...



Sharks don't get cancer

There are plenty of documented examples of sharks with cancer. This myth has been used as the pseudoscientific basis for the use of shark cartilage as an alternative cancer treatment and is implicated in diminishing shark populations. The world of alternative medicine is filled with myths that could be included on this list, but not all such myths put entire species at risk. This one does.



You need to eat five portions of fruit and veg a day

Campaigns that aim to increase the amount of fruit and vegetables the average person consumes have taken place across the world. For example, in Australia they have the '2 & 5' campaign. These campaigns are based on the World Health Organization's recommendation of 400g of fruit and veg per day.

The five-a-day target is pretty arbitrary – you probably won't be a lot worse off if you only manage four, and six would probably be slightly better. Five a day might be a reasonable target if you currently eat little or no fruit or vegetables, but there's nothing special about that figure in particular.

Superfoods are really good for you

Put simply, there is no academically recognised definition for 'superfood' – it is essentially a marketing term. While adding some berries and kale to your diet may be beneficial to your health, many of the specific claims made about various superfoods aren't based on any real evidence. No single food has shown to be a health panacea worthy of the term 'super', and no one should think they can counteract the effects of a huge bowl of ice cream by liberally sprinkling it with goji berries.



MSG is bad for you

Monosodium glutamate (MSG) is a common source of the savoury 'umami' flavour found in many foods, such as tomatoes, soy sauce and parmesan cheese. It is used as a flavour enhancer by the food industry, but claims about MSG's negative health effects have been around for a while, with supposed ill effects ranging from headaches to cancer. As a result, MSG has been studied extensively, and in 2007, a team at the University of Hohenheim examined all the research on MSG and concluded that even unusually high doses are not harmful. It has also been conclusively established that MSG makes things taste even more delicious.

Alcohol keeps you warm

Many a drinker has found alcohol makes them feel more resistant to cold weather on the walk home from the pub. This 'beer jacket' is the result of the blood vessels dilating, resulting in more blood travelling to the surface of the skin. Far from keeping you warm, alcohol is more likely to put you at risk of hypothermia as it can impair the body's ability to regulate its temperature.



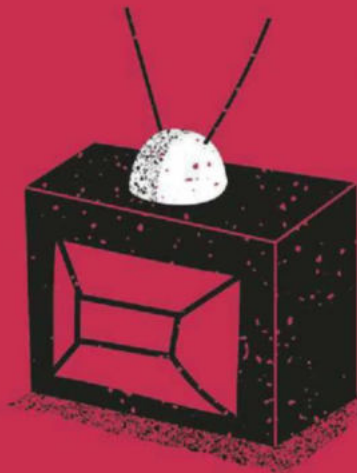
Adults can't generate new brain cells

Several areas of the adult brain contain the neural stem cells required for the growth of neurons. These areas include the dentate gyrus, thought to be involved in memory formation, and the olfactory bulb, which is involved in our sense of smell.



We only use 10 per cent of our brains

The origin of this myth is uncertain, but it didn't originate from the scientific study of the brain. The myth is often found in self-help books that claim to tell you how to harness the power of the brain's other 90 per cent. In reality, all the parts of the brain are highly specialised and there don't appear to be any unused sections that you could learn to activate in an attempt at self-improvement.



Sugar makes kids hyperactive

It's easy to understand why so many believe that sugar (a source of quick energy) causes hyperactivity, but numerous controlled experiments have failed to establish any causal relationship. The belief might be perpetuated by 'confirmation bias': a study at the University of Kentucky showed that when a parent was told that their child had just eaten a lot of sugar (even when they hadn't), the parent was far more likely to describe their kid as hyperactive. Of course, this doesn't mean feeding your children vast quantities of sugar is to be recommended.



The tongue is divided up into different sections

The absence of an umami section is not the biggest problem with the tongue map. The idea that our tongues are split into sections has been perpetuated by textbooks and teachers for decades, yet it has no basis in physiology. The receptor cells that identify the molecules underlying the basic tastes (sweet, sour, salt, bitter and umami) are distributed all over the tongue.



Caffeine dehydrates you

You may find yourself visiting the bathroom more frequently after consuming tea or coffee. This is probably due to the diuretic effect of caffeine, which is suspected to irritate muscles in the bladder. But even if you do pee more often, it doesn't mean you're passing a greater volume overall. The effect of caffeine on urine output has been investigated in numerous studies, which have been reviewed by dietician Dr Carrie Ruxton. She found that a moderate intake of caffeinated drinks is unlikely to have any significant effect on your overall level of hydration. ●

MYTH-BUSTING

Ginger-haired people are going extinct

Red hair is caused by a recessive variant of a gene, which means you need two copies of it to be a redhead. Currently, redhead alleles are found at a much higher concentration in some populations in northern and western Europe. It's possible that as those genes spread out the probability of two people with a redhead allele having a child will diminish, which might make redheads less common, but as long as the genes are there, we will still have redheads.



There's a chemical that turns purple when someone wees in a swimming pool

Although this myth might serve a noble purpose, there is no 'urine indicator' that could be put into pools. In principle it may be possible to create a chemical that is colourless in the absence of urine, but colourful in its presence. But the difficulty in ensuring that it doesn't result in false positives probably wouldn't be worth the investment. Along with the difficulties in developing such a dye, you could probably also guarantee that any pool that used it would have a constant purple tinge.

Left-brained people are logical, right-brained people are creative

As described by the University of Utah's Jared Nielsen in a study of brain scans from over 1,000 individuals, there is no evidence of left- or right-brain dominance. The idea that there are left-brained people who are logical and right-brained people who are creative may be a useful metaphor, but it has no more basis in actual science than astrology does. Though a left-brained Gemini like myself would say that.

Shaving causes hair to grow back faster and thicker

Shaved hair that hasn't yet been exposed to the bleaching effects of sunlight may appear darker. And compared to the tapered end of an unshaved strand of hair, the sheared ends usually feel coarser. While these two effects might make recently shaved hair seem thicker, there is no evidence that shaving influences the growth rate or thickness of hair.



You lose a lot of body heat through your head

If you leave any one body part exposed to the elements, that body part will play a major part in your heat loss. The 7 per cent of your body's surface area that covers your head isn't in any way special, however. The myth often claims a figure of around 50 per cent heat loss through the head. The implication of this percentage is that you'd be as warm if you went out wearing nothing but a balaclava as you would be if you went out fully clothed but without a hat. Feel free to try this at home.



Barefoot running is better for you

Barefoot running has grown in popularity over the past few years. The proponents usually claim that running without traditional running shoes improves form, prevents high impact 'heel strikes' and reduces injury rates. However, media articles supporting barefoot running generally rely on questionable evolutionary hypotheses or anecdotes. A group of researchers at the University of Cape Town examined papers looking at the biomechanics of barefoot versus traditional running. Dr Nicholas Tam and his team concluded that while barefoot running might reduce the risk of certain injuries, such as knee pain, it may also increase the risk of others, such as stress fractures to the feet. Individual experience may vary, but there is so far no scientific basis on which to prescribe barefoot running to reduce injury rates.

Stretching before exercise prevents injury

Finnish researchers analysed studies covering almost 5,000 participants and concluded that stretching before exercise had no effect on injury rates. However, a gentle aerobic warm-up will prepare the muscles for a workout.

People are more likely to commit suicide in winter


The assumption that the dark and cold of winter cause a peak in suicides is understandable, but it's not supported by the statistics. Researchers from Inje University in Seoul looked at studies from a range of countries, and found that the biggest peak is around April and May (in the northern hemisphere). This peak also varies based on a number of demographic factors, particularly age. The seasonal variation in the suicide rate is smaller in the UK, but winter is not the most dangerous period.

Playing classical music to babies makes them grow up smarter


There may or may not be a correlation between intelligence and an appreciation for classical music. 'The Mozart Effect' that suggests classical music improves children's intelligence was first described in an early 1990s study, but since then, it has not been established as a robust phenomenon that survives study replication. Parents' time is probably better spent teaching their children that correlation does not imply causation.



A malfunction at a particle accelerator could suck the entire planet into a black hole

The idea that particle accelerators, particularly the Large Hadron Collider (LHC), might cause Earth-threatening black holes has been in the news since the LHC opened. Micro black holes are hypothesised to be generated by high-energy particle accelerators like the LHC, but they wouldn't be a threat to the planet. Unlike their massive astronomical cousins, the hypothetical micro black holes would evaporate almost instantly. And although it would be an important discovery, no micro black holes have been detected at the LHC so far. 

Tobias Jolly is a data analyst and biochemistry graduate.

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ROBERT MATTHEWS... THE TROUBLE WITH GENIUSES

"WHY ARE BRILLIANT SCIENTISTS SEDUCED INTO SPENDING TIME ON THE NATURE OF CONSCIOUSNESS?"

Everyone has childhood heroes – a brilliant sports star, say, or an adventurer. It's all part of growing up – as is discovering they weren't quite as heroic as you thought. My first hero was Captain Scott, whose story of steely determination to reach the South Pole moved me to tears when I read it as a kid. Only years later did I find out that he was an amateurish bungler.

My scientific heroes have fared better. Sure, Louis Pasteur sometimes cut corners in his scientific studies of disease, but the outcome saved countless lives. Physicist Richard Feynman was a bit of a show-off, but there's no doubting his genius.

And then there's Albert Einstein, who just gets more impressive by the day. His theories are still producing the goods a century on – witness the recent detection of gravitational waves. Yet even he made mistakes. He never accepted quantum theory, and wasted years searching for a theory that unified the fundamental forces of nature.

The tragedy of Einstein's lost years is that it was clear his quest was doomed even as he worked on it. His rejection of quantum theory ruled out any hope of understanding the subatomic world. Then there's the awkward fact that when Einstein started work, 'everything' involved just two forces of nature – gravity and electromagnetism. As the years went by, other fundamental forces were identified, but they didn't stop Einstein. He was still working on his Theory of Some Bits of Everything on the day he died.

Still, it's the prerogative of all geniuses to pursue their own hobbyhorses, isn't it? Maybe, but I can't help being saddened when I learn that yet another brilliant scientist has been seduced into spending time on one particular Big Question: the nature of consciousness.



Pondering how our brains create the sense of being conscious has entranced countless thinkers, from René Descartes to Nobel laureates like Francis Crick of DNA fame. None of them made any real progress, in the sense of developing theories that could be tested scientifically.

And yet still they come. As you read this, some very clever people are in Arizona for the most prestigious conference devoted to the problem of consciousness.

Held every other year since 1994, the week-long gathering

used to be called Towards a Science of Consciousness. But it's been renamed The Science of Consciousness.

So after centuries of conjecture, beard-stroking and thought, have the great minds nailed down the problem to the point they can put rival theories to the test? Er, no, not exactly. The conference features the usual grab-bag of imponderables being kicked around by the usual mix of cerebral celebs. In short, the name change is just an exercise in rebranding – the scientific equivalent of steaming the label off a bottle of plonk and renaming it Château Lafite.

Part of the conference has been designated the Pribram Session, named after Karl Pribram, one of the pioneers of brain research who died last year at the age of 95. He was yet another brilliant scientist who spent his latter years wrestling with the mystery of consciousness. The outcome was an enormous book whose thesis is flaky at best.

I'm sure that Pribram's peers will have a grand time in Arizona. But part of me wishes they would bend their intellects towards problems they can at least agree on.

Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest book *Chancing It: The Laws Of Chance And What They Mean For You* is out now (Profile, £14.99).

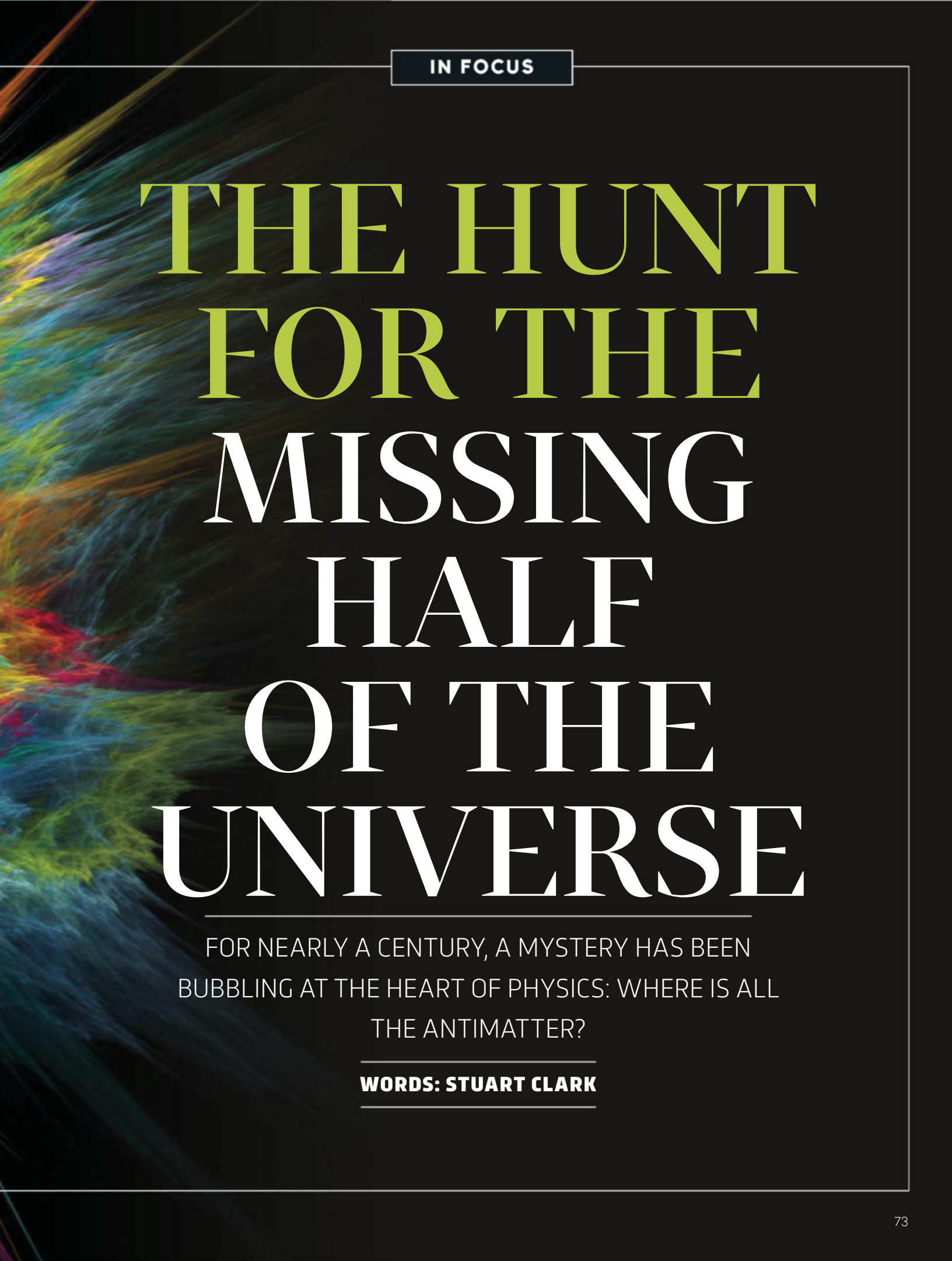
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Artist's impression of the Big Bang



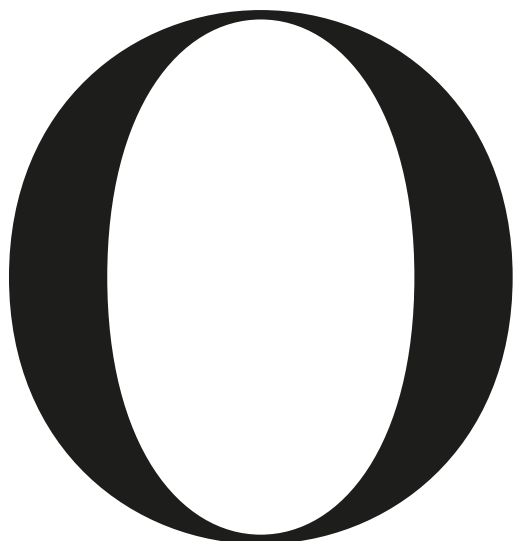
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THE HUNT FOR THE MISSING HALF OF THE UNIVERSE

FOR NEARLY A CENTURY, A MYSTERY HAS BEEN
BUBBLING AT THE HEART OF PHYSICS: WHERE IS ALL
THE ANTIMATTER?

WORDS: STUART CLARK



ne of the greatest mysteries in physics is ‘why is there any matter in the Universe at all?’ All of the stars and planets, galaxies and clusters are made of the stuff. Even plants and animals are made of matter. But according to our understandings of the origin of the Universe and antimatter, none of it should exist.

The most important aspect of antimatter is that when it meets a matter particle counterpart, both are annihilated back into energy. A reading of the laws of physics suggests that the tremendous outpouring of energy that took place in the Big Bang should have created equal amounts of matter and antimatter, and that’s a big problem because here we are 13.8 billion years later and the Universe is still full of celestial objects. All of them are made from matter.

So, the conclusion is inescapable: nature simply did not produce as much antimatter as matter. Comparing the amount of radiation to matter in the Universe, our best estimates suggest that for every billion particles of antimatter that were formed, a billion and one particles of matter came into

existence. When the particles and antiparticles annihilated back into energy, the residue went on to form the shining structures that we see right across space.

All of this means that there is something missing from our equations of physics. There is a miscalculation that must be tracked down and corrected. At the root of the problem must be some big piece of physics that we simply do not yet understand. As a result, many particle physicists have turned their attention to solving the problem.

MISSING ANTIMATTER

The story of the missing antimatter began in 1928. At the time, physics was in a state

of seismic change. Albert Einstein had established relativity as a way of describing the force of gravity and some of the strange effects that happen when objects move at close to the speed of light. Almost simultaneously, a group of physicists were developing quantum mechanics – a way of describing the behaviour of particles. Meanwhile, British physicist Paul Dirac was trying to link the two theories, by applying Einstein’s relativity to the quantum mechanics of hydrogen atoms.

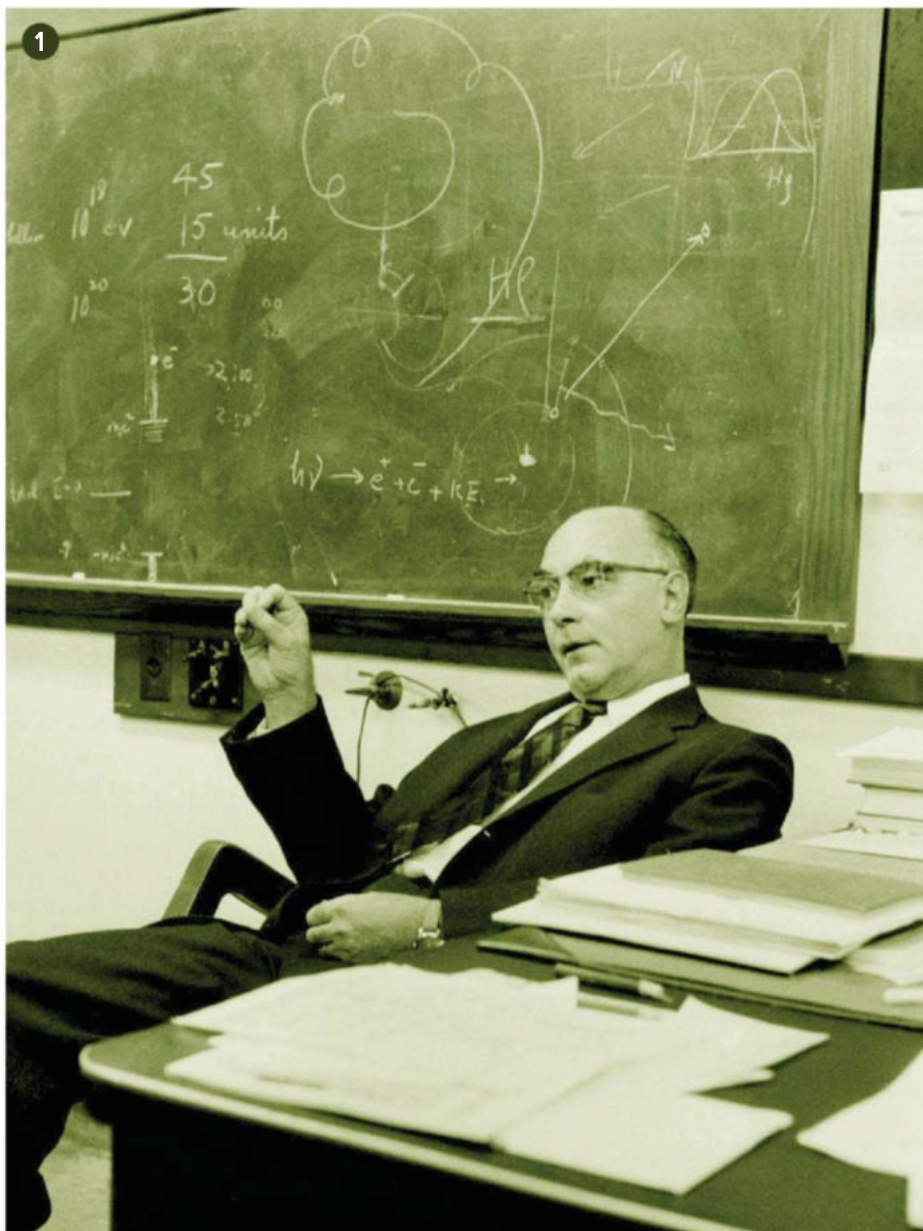
In the resulting equations, he saw that it was possible for a particle to exist that shared the characteristics of an electron. However, instead of being negatively charged like an electron, it was positively charged. It was our first inkling that antimatter could exist. Dirac developed the idea and published his prediction of the ‘anti-electron’ in 1931.

Concurrent with Dirac’s theoretical work, a number of experimentalists had been noting odd observations in their laboratory ‘cloud chambers’. These sealed tanks contain a supersaturated mixture of water vapour and alcohol. When a tiny particle passes through the tank, it leaves a trail of mist. Applying a magnetic field across the chamber means that electrically charged particles are deflected, producing curving tracks. Some scientists noticed that electrons sometimes appeared to curve the wrong way.

US physicist Carl Anderson wondered if these observations could be produced by Dirac’s positive electrons, and so built his own experiment to test the idea. On 2 August 1932, he gathered enough data to be sure that the ‘anti-electrons’ existed. He named them ‘positrons’ at the suggestions of the editor of the journal *Physical Review* that printed the landmark paper. Since then, antimatter has become a familiar part of physics and science fiction but with the positive identification came the realisation that something was wrong at the heart of physics.

Dirac’s equations suggested that antimatter would obey the laws of nature in the same way as ordinary matter. In this case, there must be exactly equal quantities of matter and antimatter in the Universe and so somewhere there would have to be ●

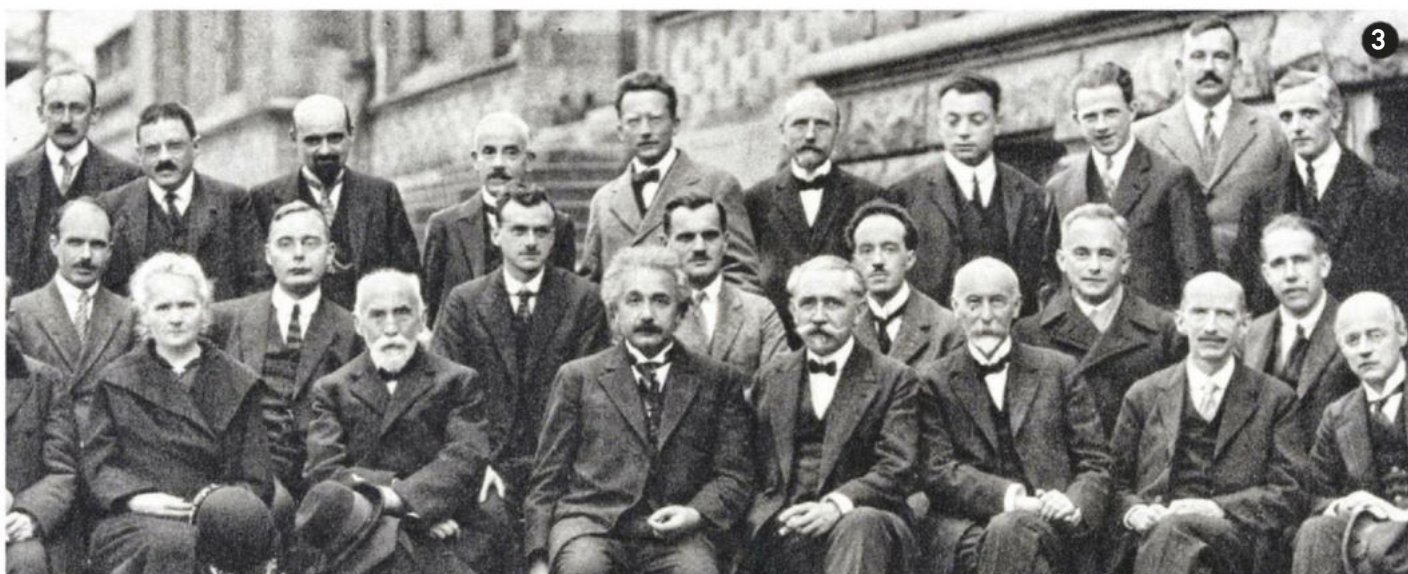
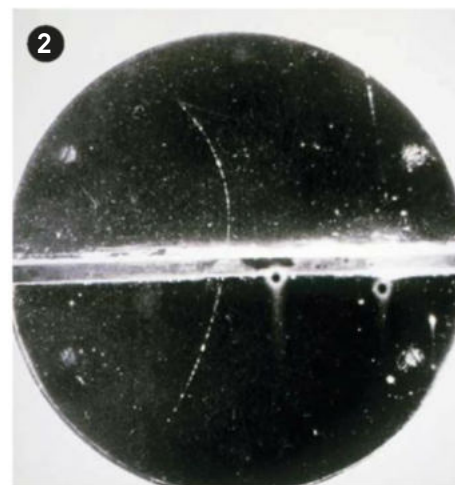
“According to our knowledge of the Universe’s origin, matter and antimatter should not exist”



1 US physicist Carl Anderson jointly received the 1936 Nobel Prize for Physics for his 1932 discovery of the positron, the antiparticle of the electron

2 The first image of the positron, taken in a cloud chamber. The positron's trail can be seen curving to the left in the middle of the picture

3 At the 1927 Solvay Conference, renowned scientists gathered to discuss electrons, photons and quantum theory. A few key figures were: Marie Curie (first row, far left); Albert Einstein (first row, third from left); Paul Dirac (second row, third from left); Niels Bohr (second row, far right). How many do you recognise?



The Bullet Cluster comprises two colliding clusters of galaxies, and was studied in an attempt to detect antimatter

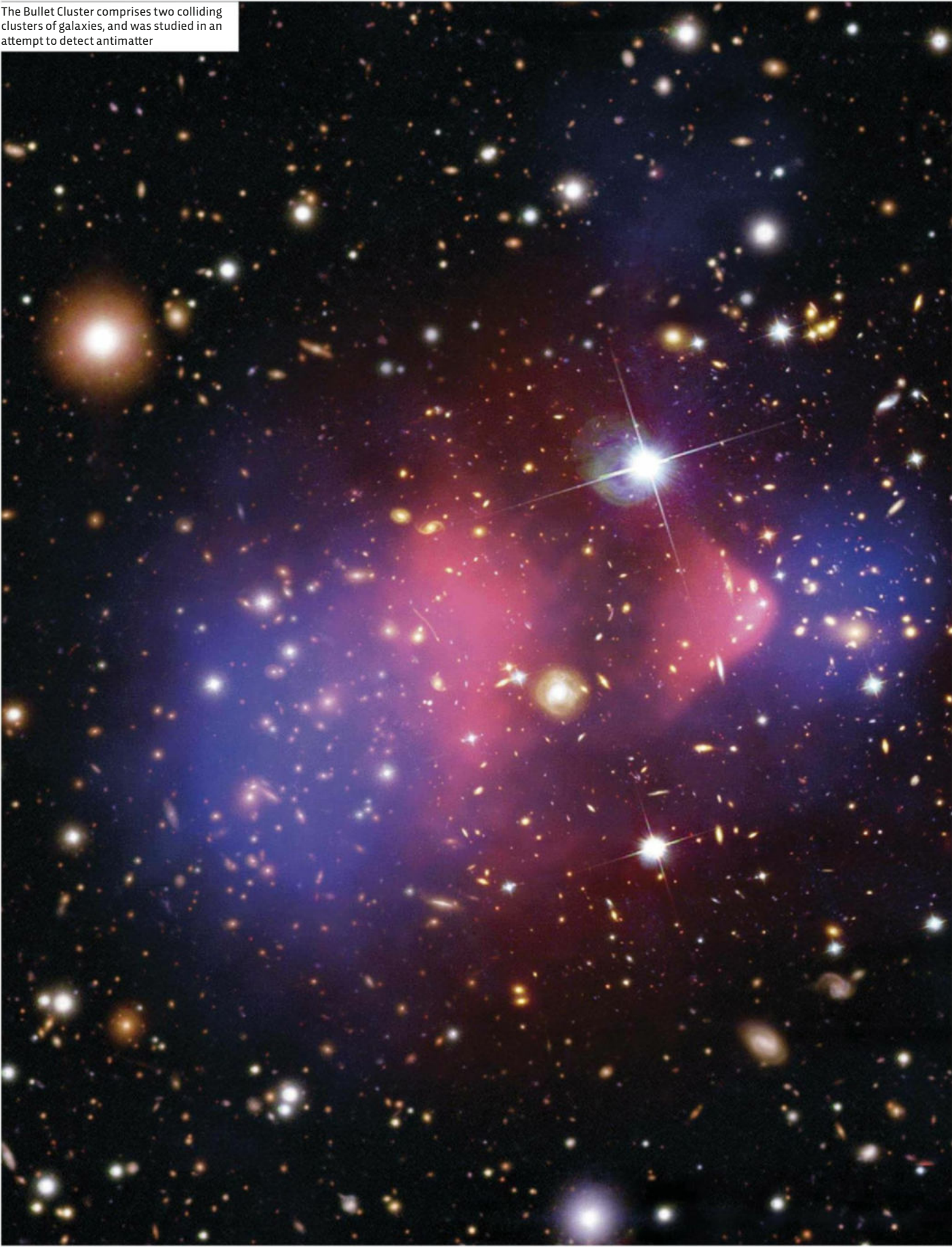


PHOTO: NASA/HUBBLE SPACE TELESCOPE

“It is not just black holes that release antimatter. Every hour or so, on average, your lunchtime banana will spit out a positron”

● antimatter stars and galaxies – but how to find them?

In the late 1970s, Russian cosmologist Alexei Starobinsky published details of how the Universe could have expanded hugely in its earliest moments. This process was termed ‘cosmic inflation’ and is thought to be a strong possibility for what happened shortly after the Big Bang. If the distribution of matter and antimatter were not completely uniform, then it is possible that inflation separated out the clouds of matter and antimatter and carried them to different parts of the Universe. As antimatter stars would give out ordinary light, it is impossible whether they are made of matter or antimatter just by looking at them.

SMASHING STARS

In 2008, Prof Gary Steigman of Ohio State University realised that there could be another way to identify antimatter. Sometimes, huge clusters of galaxies collide with each other. If one were made of matter and the other of antimatter, then the particles would annihilate each other to give off far more X-rays and gamma rays than would normally be expected. To search for antimatter, Steigman investigated a galactic smash-up known as the Bullet Cluster. He studied observations of it made by NASA’s Chandra X-ray Observatory and Compton Gamma Ray Observatory, but found nothing of significance. The low level of X-rays and gamma rays implied that less than three particles in every million could be antimatter.

In the same year, a vast but tenuous cloud of antimatter was found in our very own Milky Way. It surrounds the centre of the Galaxy and shows itself by the gamma rays it gives out. These carry the precise amount of energy released by the collision of an electron and a positron.

Observations with the European Space Agency’s INTEGRAL gamma-ray satellite showed that the cloud is not precisely centred on the Milky Way, but instead seems to trace the pattern of stars that are known to give out X-rays. The antimatter is therefore not left over from the beginning of the Universe. Instead, it seems that the stars themselves are the source of the positrons. Each one is orbited by a black

hole, and the antimatter is produced in the high-energy processes that take place as the gas from each star is ripped away and eaten by its companion black hole.

It is not just black holes that release antimatter. Every hour or so, on average, your lunchtime banana spits out a positron. This is because bananas contain the naturally occurring radioactive isotope potassium-40. As it decays, the isotope occasionally releases a positron, which will

annihilate into energy with the first electron it encounters. The amount of energy released in the annihilation is minuscule. Indeed, there is potassium-40 in our bodies too, and the same process takes place.

The bottom line is that when it comes to searching for primordial antimatter, finding positrons just will not do. They are too easy to produce in the modern Universe. Instead, heavier antimatter particles such as anti-helium nuclei are needed. To look for these, astronomers comb the so-called cosmic rays that perpetually bombard our atmosphere.

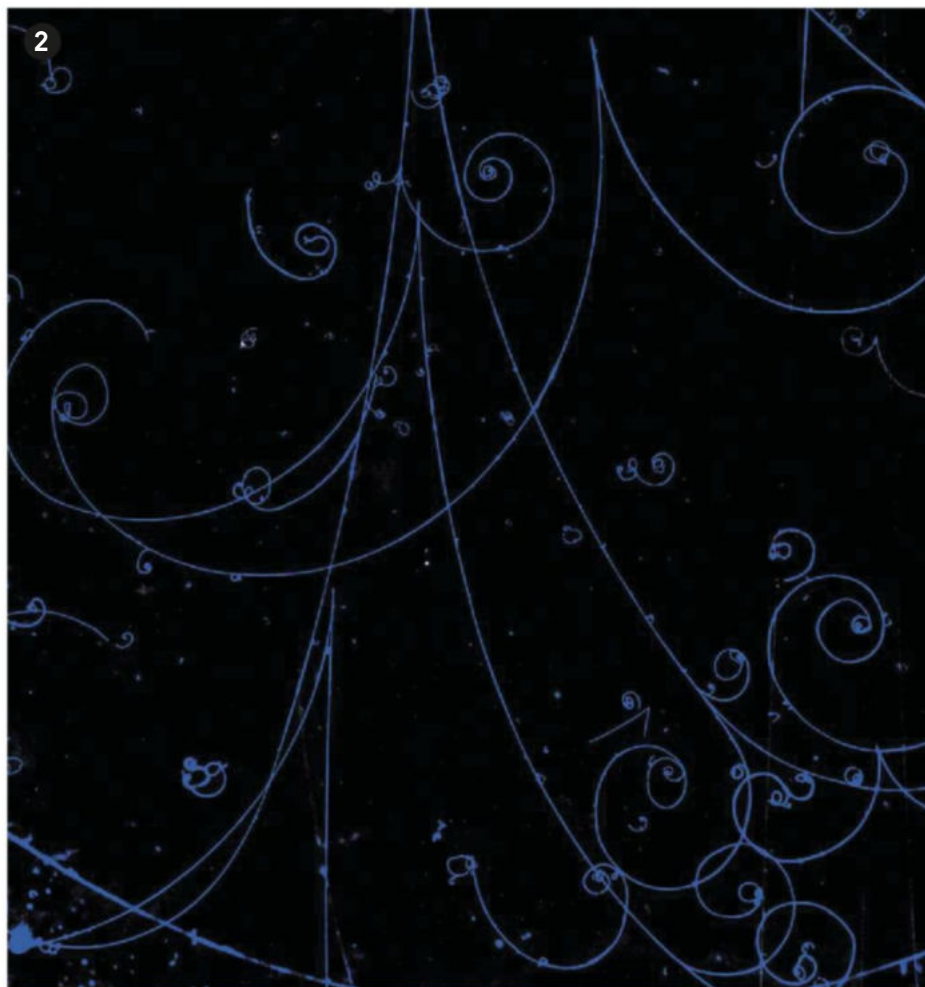
RAY OF INSPIRATION

Between 1911 and 1913, the Austrian physicist Victor Hess repeatedly climbed into a hot air balloon. These were no pleasure rides. Instead, he was carrying particle detectors. Since the discovery of radioactivity in the late-19th Century, it was assumed that the level of particle radiation would decrease with altitude since it was thought that the radiation measured at sea level was coming from radioactive elements in the rocks. Hess set out to test this.

In a series of ever higher balloon flights, he produced a surprising result: that the amount of radiation in his detectors increased with altitude. It was completely against everyone’s expectations. Physicists next assumed that if the radiation was coming from space, it must be coming from the Sun. Hess tested this as well. He took a balloon flight during a total solar eclipse and discovered that the amount of radiation increased as usual even though the Moon was completely blocking the Sun. He concluded that the radiation was coming from deep space. Known as cosmic rays, the phenomenon quickly became a focus for physicists to investigate ●

1 Austrian physicist Victor Hess made trips in a hot air balloon to measure radiation. He found that levels increase with altitude, concluding that the radiation comes from outer space – a discovery that bagged him a joint Nobel Prize in Physics in 1936

2 These tracks show a shower of particles, moving from top to bottom through a chamber. The tracks spiralling anticlockwise are produced by electrons, while positrons are spiralling clockwise



and in 1936, positrons were discovered in them. While positrons can be created in present-day interactions, the cosmic rays present a way to trawl for unmistakable traces of primordial antimatter.

SEARCHING SPACE

There is nothing powerful enough in nature today to produce a nucleus of anti-helium. Only the Big Bang can do that. So, if such a particle were to be discovered, then it would have to be a piece of primordial antimatter. A bigger prize would be the detection of a nucleus of anti-carbon. Carbon can only be made in the nuclear furnaces found inside stars. An anti-carbon nucleus would therefore mean that there were antimatter stars somewhere out there in space – a dramatic breakthrough indeed.

In 2011, the Alpha Magnetic Spectrometer (AMS) detector was carried into orbit by the space shuttle Endeavour and placed on the International Space Station (ISS). The AMS was designed specifically to measure the amount and type of antimatter in cosmic rays; by 2013 it had seen more than 400,000 positrons but not a single piece of any other antimatter.

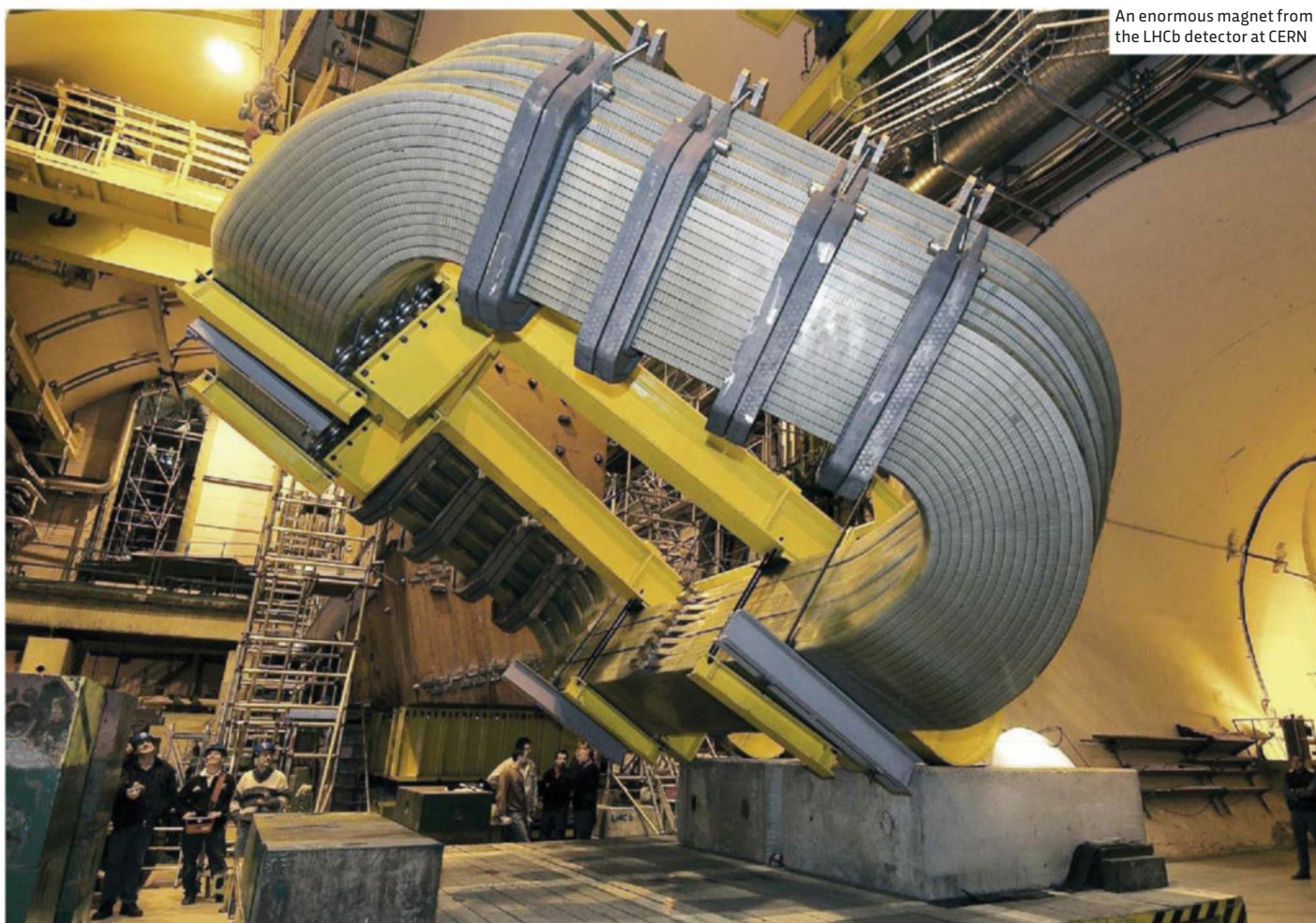
The truth is that so far there is no evidence that primordial antimatter is lurking anywhere in space. So that leaves just one possibility: contrary to Dirac's equations, antimatter behaves differently from matter.

In 1967, Russian physicist Andrei Sakharov proposed a set of conditions that would lead to matter's dominance. The key to his proposal was that in the extreme conditions of the Big Bang, the laws of physics must have acted slightly differently on matter than on antimatter.

In the decades since, particle physics experiments have repeatedly seen that there is a wrinkle in physics that means particles and antiparticles behave a little differently from each other. It can be traced to the so-called weak nuclear force. This is one of the four fundamental forces of nature. Gravity and electromagnetism are two of these forces. These operate on the largest scales across the Universe. The final force is the strong nuclear force. Like the weak nuclear force, this acts on short ranges that are comparable to the size of an atomic nucleus.

In 1964, physicists studying particles called kaons noticed that the kaons could naturally

“The laws of physics must have acted slightly differently on matter than on antimatter”



An enormous magnet from the LHCb detector at CERN

decay into their antiparticles but that the decay of anti-kaons into matter happened with a different frequency. In other words, the two processes were not mirror images of one another and so would lead to an excess of matter in the Universe. In the decades since, particle physicists have seen similar readings, time after time.

The latest experiments have been taking place at CERN's Large Hadron Collider. The detector known as LHCb has been supplying evidence that matter and antimatter behave differently when responding to the weak nuclear force. This has allowed the scientists to define a number that quantifies the difference, which can be used to see how much antimatter was produced in the early Universe. The answer is not what the scientists were hoping for. It goes in completely the wrong direction.

Remember, the split between matter and antimatter is expected to be a billion particles of antimatter produced for every billion and one particles of matter. So, roughly speaking, half the Universe was antimatter in those early days. Yet according to the experiments seen so far, the early Universe should only have produced about a galaxy's worth of antimatter. This is a clear mismatch between expectation and observation, and it means that there is a lot more work to do.

One consideration is that experiments carried out so far have only concentrated on subatomic particles called quarks. These make up the particles found in the nuclei of atoms. There is another whole family of particles called leptons – which includes electrons – that also respond to the weak nuclear force. Perhaps experiments will show that their behaviour can match our expectations and solve the problem.

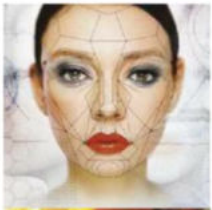
For now, physicists remain mystified about how and why antimatter should behave differently to matter. Yet the evidence for it doing so is spread across the whole Universe. Perhaps the solution will come during the next run of the Large Hadron Collider. There is some evidence that a new particle of nature has been seen. The detection is still to be confirmed, but if true, this particle has not been predicted from any known theory. If it is really truly there, it will need explaining, and who knows what secrets it might reveal about the Universe. 🌌

Stuart Clark is an astrophysicist and writer. His most recent book is *The Unknown Universe*.

DISCOVER MORE



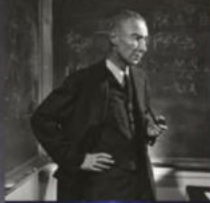
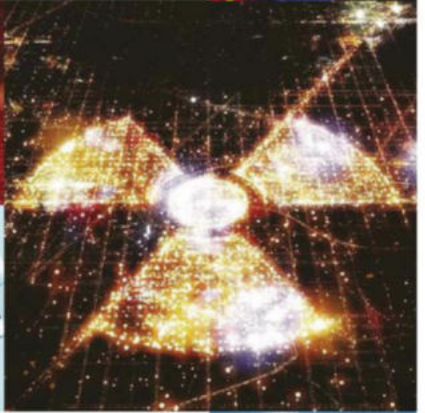
Watch BBC Four's *The Sky At Night* every month for the latest news on the cosmos.



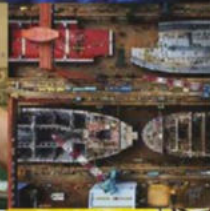
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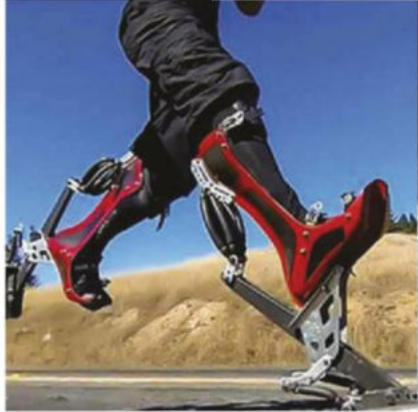
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THE ULTIMATE MAGAZINE FOR CURIOUS MINDS



DR CHRISTIAN JARRETT
Christian is a psychology and neuroscience writer. His latest book is *Great Myths Of The Brain*.



DR ALASTAIR GUNN
Alastair is an astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



PROF ROBERT MATTHEWS
Robert is a physicist and science writer. He's visiting professor in science at Aston University.



DR PETER J BENTLEY
Peter is a computer scientist and author who is based at University College London. His latest book is *Digitized*.



LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology. He is author of *How Cows Reach The Ground*.

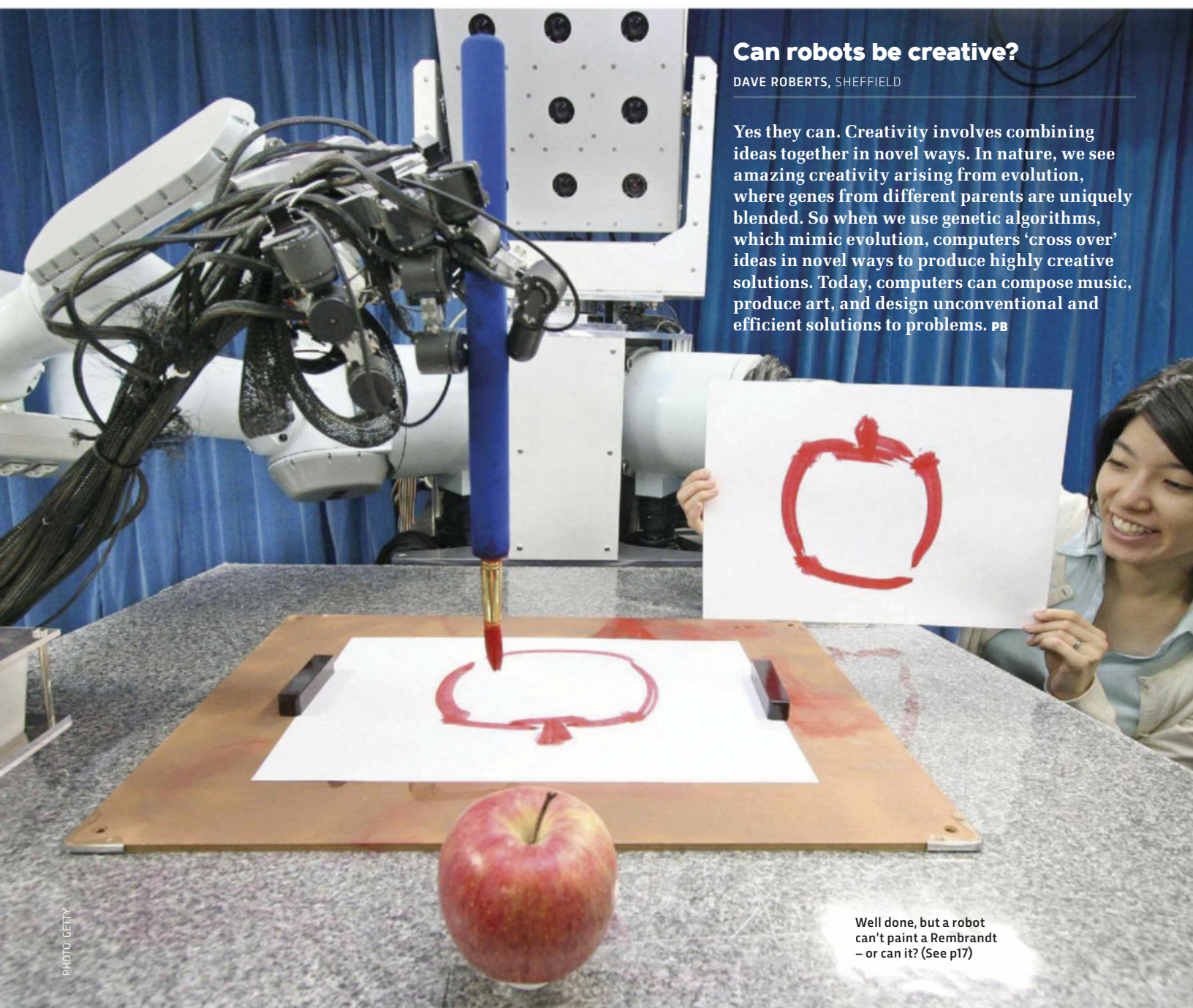


DR MARK LORCH
Mark is a senior lecturer at the University of Hull, where he teaches chemistry and science.

YOUR QUESTIONS ANSWERED

MAY 2016

EDITED BY EMMA BAYLEY



Can robots be creative?

DAVE ROBERTS, SHEFFIELD

Yes they can. Creativity involves combining ideas together in novel ways. In nature, we see amazing creativity arising from evolution, where genes from different parents are uniquely blended. So when we use genetic algorithms, which mimic evolution, computers 'cross over' ideas in novel ways to produce highly creative solutions. Today, computers can compose music, produce art, and design unconventional and efficient solutions to problems. **PB**

Well done, but a robot can't paint a Rembrandt – or can it? (See p17)

IN NUMBERS

92
hours

is the record for non-stop
TV watching, set by five
Austrians in early 2016

75

hamburgers are sold by
McDonald's around the
world every second

Are offices making us more sick?

SAMANTHA MORRIS, LONDON

It's hard to be sure. Several studies have found that workers in open-plan offices take more sick days than those who work in small groups or have their own private office. But this is mostly short absences of just one or two days. If cold viruses were spreading more effectively in offices, you would also expect the spread of flu as well, which would knock you out for at least

a week. So maybe open-plan offices are just more stressful and unpleasant to work in, and their employees are more inclined to 'pull a sickie'. Or it may be that open-plan employees are less likely to be missed. A 2005 study found that 'presenteeism' (where employees come to work, even when they are sick) is more common in small offices. **LV**



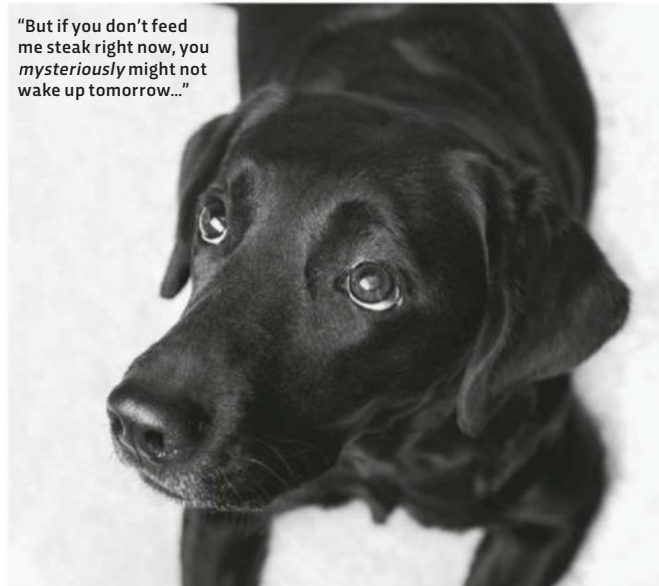
Extreme measures are
put in place when Barry
eats curry for lunch

Can dogs sense when someone is about to die?

ALEXANDRA ICHIM, DUBLIN, IRELAND

Dogs are highly social animals and certainly sense when we are unhappy or in pain. A 2004 study also found that they can be trained to detect bladder cancer from the smell of the patient's urine. So it's certainly possible that dogs may be able to tell when someone is seriously ill. But there's no evidence that they have any sixth sense that can tell you'll be hit by a bus tomorrow. **LV**

"But if you don't feed
me steak right now, you
mysteriously might not
wake up tomorrow..."

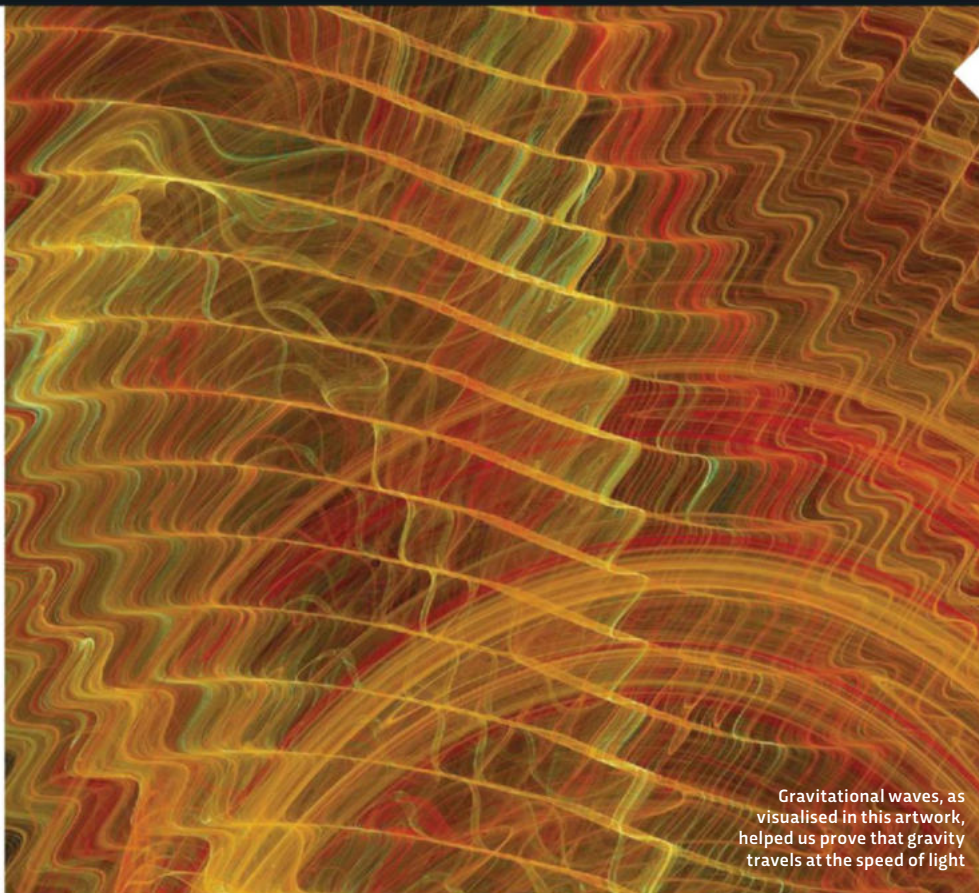


What does sleep do for the brain?

SARAH COOPER, MANCHESTER

Too much stimulation of your brain cells can lead to neurotoxicity, which is dangerous, and so one tentative theory holds that sleep is a chance for the brain to enter a detox mode in which overall levels of neural excitability are reduced. Sleep also helps the brain to learn, although the precise physiological processes that underlie this benefit are still being worked out. This means that after you've spent time revising or learning a new skill, it's very important that you get a good night's sleep. Doing so will help your brain to consolidate the neural connections that underlie new memories. **cj**





Gravitational waves, as visualised in this artwork, helped us prove that gravity travels at the speed of light

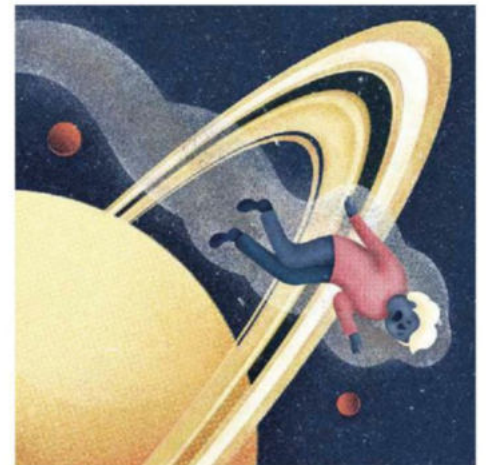
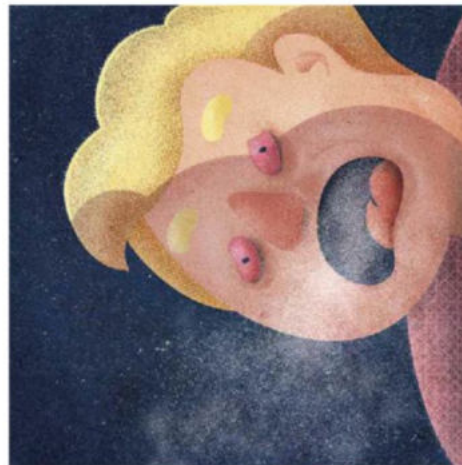
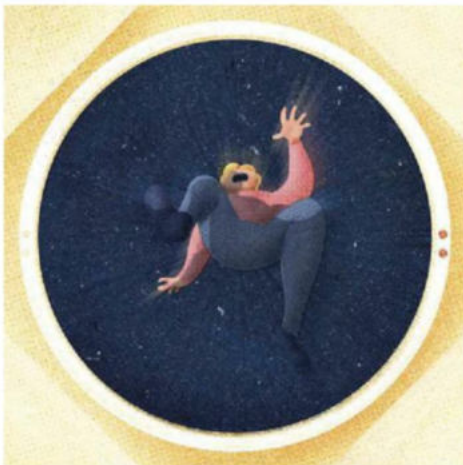
What is the speed of gravity?

KONOR LAMBRINIDIS, STIRLING

According to Einstein's General Relativity, gravity travels at the speed of light. Proving it is far from simple, though: unlike light, gravity can't simply be switched on and off, and is also extremely weak. Over the years, various attempts have been made to measure the speed using studies of astronomical phenomena, such as the time delay of light as it passes through the huge gravitational field of Jupiter. While the results have been broadly in line with Einstein's prediction, they've lacked the precision needed for compelling evidence. That's now been provided by the celebrated detection of gravitational waves. Analysis of the signals picked up by the two giant LIGO instruments in the US has confirmed that gravity does indeed travel through space at the speed of light. **RM**

THE THOUGHT EXPERIMENT

WHAT WILL HAPPEN IF I AM JETTISONED INTO SPACE?



1. YOU WON'T EXPLODE

Even without a spacesuit, your skin can resist a pressure difference of one atmosphere, so you won't explode. Don't hold your breath though, because without the atmosphere pushing against your chest, the air trapped in your lungs will expand and rupture the tissues inside, forcing air into your chest cavity and blood, like the worst case of the bends.

2. YOU WILL ASPHYXIMATE

Since you aren't holding your breath, you have 15 seconds before you lose consciousness, or as few as five seconds if you are panicking. If you are rescued and restored to normal atmospheric pressure within 90 seconds, you have a good chance of making a recovery. But any longer than that, your heart will stop and even a defibrillator won't save you.

3. YOU'LL FREEZE DRY

In the vacuum of space, water will boil even at body temperature, so the moisture in your lungs, mouth and eyes will boil away a few minutes after you die, eventually drying you out like a mummy. And with no ozone layer to shield you from the Sun's UV radiation, your desiccated corpse will char black over the next few months.

What evolved first: eyes or ears?

CORBEN JUBIAN, SYDNEY, AUSTRALIA

The eyes can clearly be seen on this fossilised trilobite



Eyes, by at least 40 million years. The only invertebrates with ears are land arthropods and they didn't emerge until about 480 million years ago. Older invertebrates had antennae that would have been able to sense vibrations in the water, but that's not

quite the same thing as hearing. Trilobites already had complex compound eyes 521 million years ago, and simple eyespots without a lens probably date back to 570 million years ago, when the first multicellular animals appeared. **LV**



TOP 10

TOP 10 LARGEST BIRDS OF PREY (BY WEIGHT)



10. Golden eagle

Weight: 7kg
Distribution: North America, Eurasia and North Africa



8= Philippine eagle

Weight: 8kg
Distribution: Philippines



8= Lammergeier

Weight: 8kg
Distribution: Southern Europe, Middle East, China and Africa



6= Steller's sea eagle

Weight: 9kg
Distribution: Russia and Japan



6= Harpy eagle

Weight: 9kg
Distribution: Mexico, Central and South America



5. California condor

Weight: 12kg
Distribution: North America



4. Himalayan vulture

Weight: 12.5kg
Distribution: Central Asia and Himalayas



2= Lappet-faced vulture

Weight: 14kg
Distribution: Africa and Middle East



2= Eurasian black vulture

Weight: 14kg
Distribution: South Europe and Central Asia



1. Andean condor

Weight: 15kg
Distribution: South America



Is it possible to fool fingerprint readers?

MARY BROOKS, CANTERBURY



It depends on the technology used within the fingerprint reader, but it is quite possible to trick many of them. Some will be fooled by a

mould of your finger made out of the same gelatin as gummy bears – the gelatin has a similar electrical conductivity as your finger. Some will be deceived by a fingerprint on a simple piece of sticky tape. Some are even outfoxed by a simple photocopied image of a fingerprint. Most are not aware if the owner of the finger is alive or dead. Like all security systems, fingerprint readers are not perfect. **PB**

Which planet, if it disappeared, would affect Earth the most?

LIZZIE HAYNES, BROMLEY

Jupiter, which has a mass three times the combined mass of all the other planets, dominates gravitational interactions within the Solar System. But even if it suddenly disappeared there would be very little impact on the movements of the other planets, which are mostly determined by the Sun's gravity. There would be minor changes in the planets' orbits about the Sun, but very little else. However, Jupiter does a great job of shepherding and absorbing small objects in the Solar System. With Jupiter gone, the main effect on Earth would be an increase in the rate of impacts from asteroids and other space flotsam. **AG**

Can gravitational waves teach us about the inside of a black hole?

VINCENT MORRIS, BECKENHAM

The recent detection of gravitational waves from the merger of two black holes was a success for astrophysics. But from the outside it is impossible to tell anything about the inside of a black hole. The shape of the signal detected by LIGO revealed the masses of the two merging black holes, which led to an estimate of how powerful the event was at its source. But no observations, including those of gravitational waves, can probe beyond the event horizon of a black hole. **AG**

WHAT'S IN...

...TOOTHPASTE

Most of the ingredients in toothpaste are there to make it taste, smell and feel nice, act as preservatives, or bind everything together. The rest of the ingredients that are actually included for the good of your mouth include:

SODIUM FLUORIDE

This helps maintain the strength of tooth enamel and, despite controversies, is perfectly safe at the amounts found in toothpaste.

HYDRATED SILICA

This mild abrasive used to rub away stains and debris. Alternatively, your toothpaste of choice might contain calcium carbonate (chalk), magnesium carbonate or aluminium oxides, all of which do the same job.

SODIUM LAURYL SULPHATE

This detergent crops up in all sorts of products including shampoos, washing powder and washing-up liquids. It helps remove fats, but mostly it's just included to make a nice foam (which doesn't actually help with the cleaning but we expect bubbles in cleaning products). It's this stuff that makes orange juice taste vile after you've cleaned your teeth.


TRICLOSAN

This antibacterial agent appears in many toothpastes. It helps prevent gum disease, but it is a cause for concern after you spit. Triclosan is difficult to remove from sewage and when it enters the water systems it is toxic to some aquatic organisms.

How do tunneling machines know where they are?

NIGEL WIGHT, EXETER


To keep 1,000-tonne, 150m long Tunnel Boring Machines (TBMs) like those used for London's Crossrail project on track, engineers rely on a laser-based system. Precise reference points are set up below ground behind the TBM, and laser beams are sent out from them into receivers in the machine. This keeps the TBMs heading in the right direction to within a millimetre or so over distances of up to 100 metres. **RM**



Tunnel Boring Machines
are being used to excavate
beneath London for the
city's Crossrail project

Is there life in clouds?


PAUL LESLIE, CHELMSFORD



Yes. Up to two million tons of bacteria are lofted by air currents into the atmosphere each year, along with 55 million tons of fungal spores and an unknown quantity of algae. These microscopic life forms are thought to play an important part in the weather by causing the water vapour in clouds to precipitate into rain more often than it would in a lifeless atmosphere. **lv**

Why do we use a decimal system?

RAVI TEJA, LONDON



The most obvious answer is – as Aristotle pointed out – that we have 10 fingers, which we can use for counting and displaying the results. This may be why many cultures have adopted the decimal system, but it's not a watertight argument: some Native American tribes decided single hands are enough, resulting in quinary counting systems based on units of five. **RM**

How much saliva do we produce in a lifetime?

IQRA SHAHZAD, LONDON

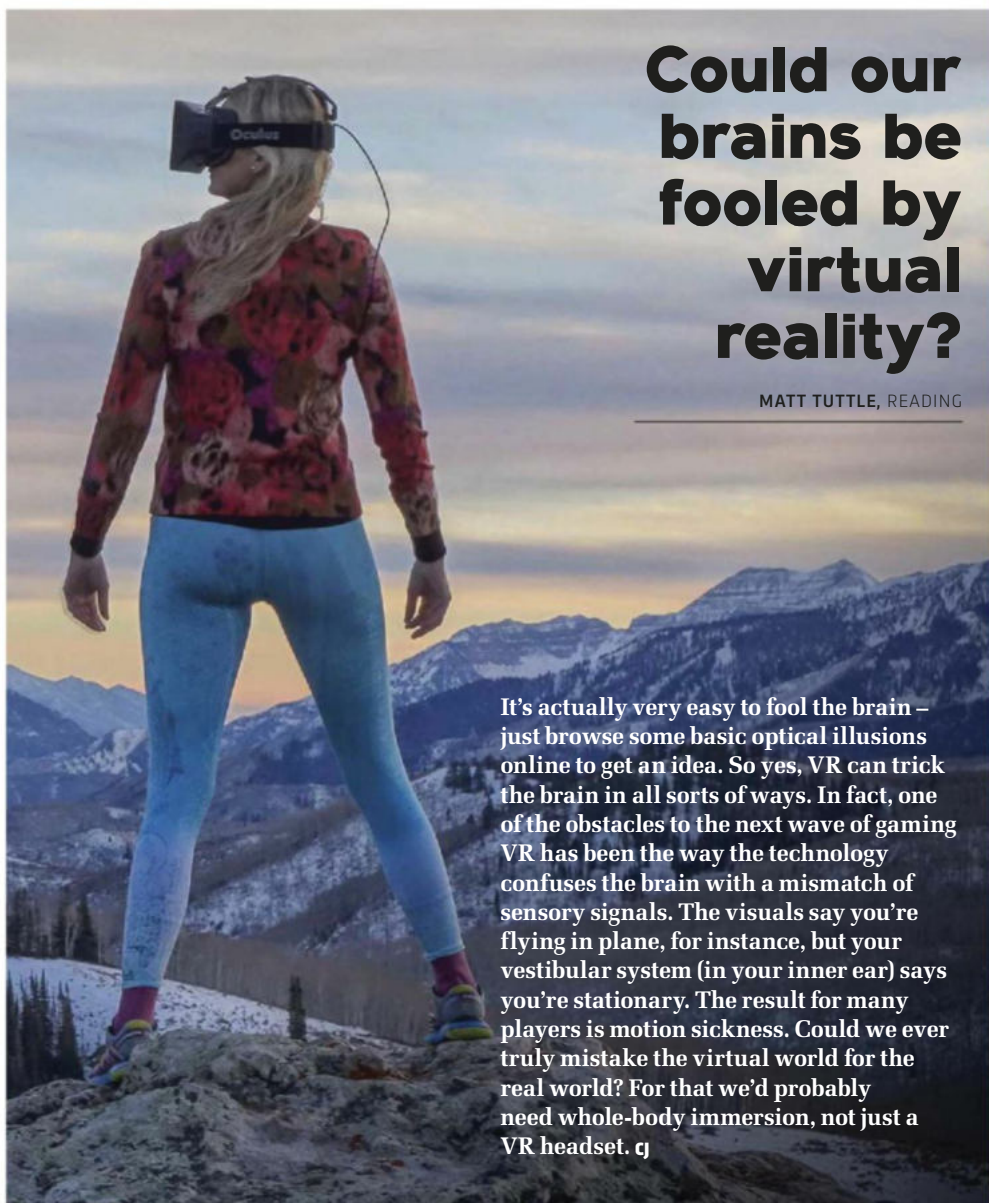
Your saliva is mostly recycled, rather than produced, because you are constantly swallowing and reabsorbing it. But the flow rate is around 30ml of saliva an hour – a bit more when you're eating, a bit less when you're sleeping. That's a wine bottle full every day, or 20,000 litres in your lifetime. In other words, 53 bathtubs full to the brim with saliva! **LV**



Could our brains be fooled by virtual reality?

MATT TUTTLE, READING

It's actually very easy to fool the brain – just browse some basic optical illusions online to get an idea. So yes, VR can trick the brain in all sorts of ways. In fact, one of the obstacles to the next wave of gaming VR has been the way the technology confuses the brain with a mismatch of sensory signals. The visuals say you're flying in plane, for instance, but your vestibular system (in your inner ear) says you're stationary. The result for many players is motion sickness. Could we ever truly mistake the virtual world for the real world? For that we'd probably need whole-body immersion, not just a VR headset. **cj**



WHAT CONNECTS...

...CAVIAR AND BEER

1.

Caviar is the eggs of a fish called a sturgeon.

The best caviar comes from the beluga sturgeon, *Huso huso*. The fish can live for over 100 years, but caviar harvesting normally kills the female.



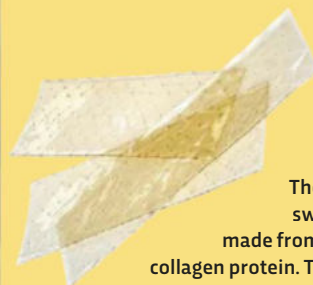
2.

Like most bony fish, the beluga sturgeon has an organ called the swim bladder. This is a gas-filled float that can be squeezed by the surrounding muscles to adjust its total volume and control the fish's buoyancy.



3.

The lining of the swim bladder is made from almost pure collagen protein. This is dried to make isinglass. The name comes from the Old Dutch word *huizenbluss* – 'sturgeon bladder'.



4.

Isinglass is traditionally added to cask-conditioned beers to remove the sediment. The collagen causes suspended particles of the brewing yeast to clump together and settle at the bottom of the barrel, resulting in a clearer beer.





WHAT IS THIS?

Crystal structure

This is the world's biggest model of a crystal's structure and was created by Dr Robert Krickl. It shows the pattern of sodium and chloride atoms found in a single crystal of table salt. The model is over three metres tall and contains almost 40,000 balls and more than 10km of connecting rods.

WHO REALLY DISCOVERED?

CALCULUS



ISAAC NEWTON



GOTTFRIED LEIBNIZ

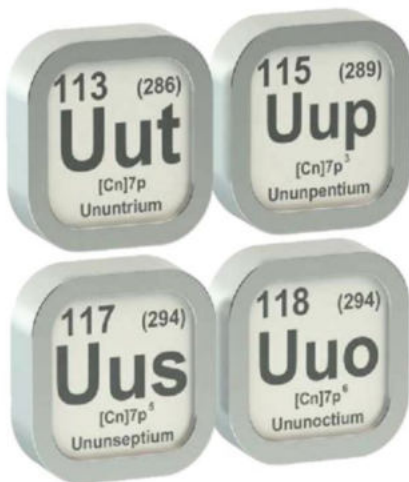
Calculus is a powerful mathematical toolbox for dealing with phenomena in a state of flux, from the flow of water to the expansion of the cosmos. As such, a better name for it would be 'fluxions' – a term coined by Isaac Newton, one of the two 17th-Century mathematicians regarded as its inventors, the other being the German Gottfried Leibniz. Not that Newton saw it that way. Having invented it in secret in the 1660s, he was horrified when Leibniz went public with similar methods, having independently discovered them about 10 years later.

Newton launched an unjustified campaign of character assassination against Leibniz, yet could not stop the adoption of his rival's name for the technique (from the Latin for 'counting stone'). It's now known that some basic ideas in calculus had been explored much earlier. For example, Archimedes showed how to work out the area enclosed by curves by dividing it up into tiny strips. This is a trick exploited in integral calculus to work out the total effect of a series of tiny changes. However, none of Leibniz and Newton's predecessors realised the full power of what they were working on.



Will we discover any more elements?

RICHARD WAITE, STOCKTON



We most definitely will! New elements are created by smashing known ones together at super-fast speeds. Ununoctium (first identified in 2002, but only recently recognised and due to get a proper name soon) is the heaviest known element and was made by firing about 40 quintillion calcium nuclei (travelling at almost the speed of light) into californium (which is itself man-made)! This made just three ununoctium atoms that hung around for about one millisecond before radioactively decaying. The laboratories that found ununoctium (and other elements) are already busy smashing more atoms together in the search for elements to start a new row of the periodic table. **ML**

NO EASY ANSWER

Could Neanderthals speak?

Forty years ago, the consensus was that they could not. Neanderthals didn't make cave paintings, or flint arrowheads, and their larynx wasn't positioned low enough to allow them to make the full range of human vocal sounds. But more recent discoveries have shown that Neanderthals had a hyoid bone, tongue nerves and hearing range that was very similar to modern humans, and quite different to other primates. Neanderthals also shared the FOXP2 gene with us, which is thought to be involved in speech and language. Prof Steven Mithen of Reading University has suggested that Neanderthals may have had a 'proto-language' that was halfway between speech and music. **LV**

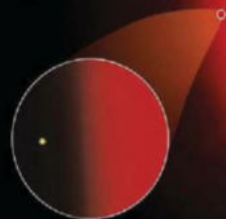


QUESTION OF THE MONTH

Do stars have a size limit?

STEPHEN BROWN, HUDDERSFIELD

Astronomers reckon that stars probably can't survive above a mass of about 150 solar masses. This is because the enormous radiation pressure and mass loss from the star would disrupt its gravitational stability. Although more massive stars have been discovered, such as the 265-solar-mass star R136a1, these are likely to form by the merger of two or more stars. But mass and physical size are not simply related, particularly for giant stars. The best candidate for the largest known star is UY Scuti which, although it is only about 30 solar masses, has a radius 1,700 times that of the Sun. Giant stars such as UY Scuti are known to swell up due to changes in their internal structure as they evolve. But there is no clear-cut equation that determines how big a star can get since it depends not only on mass, but composition, evolutionary history and the strength of its stellar wind. For giant stars, such as UY Scuti, the outer atmosphere can continue to puff up and grow essentially without limit. But at some point the diffuse gas of its outer layers become merged with the interstellar medium and cannot really be regarded as the stellar surface. **AC**



Our Sun (tiny yellow dot) compared to largest known star UY Scuti

WINNER!

Stephen Brown wins a FUZE T2-SE-C case. It's compatible with a Raspberry Pi and is a great platform to learn coding (£99.99, fuze.co.uk)



IN NUMBERS

48
million

people drink tea in the UK every day

25
per cent

of an apple's volume is air, which is why they float



What effect does drinking too much water have on your body?

MEDIUM ATOMIC WEIGHT VIA TWITTER

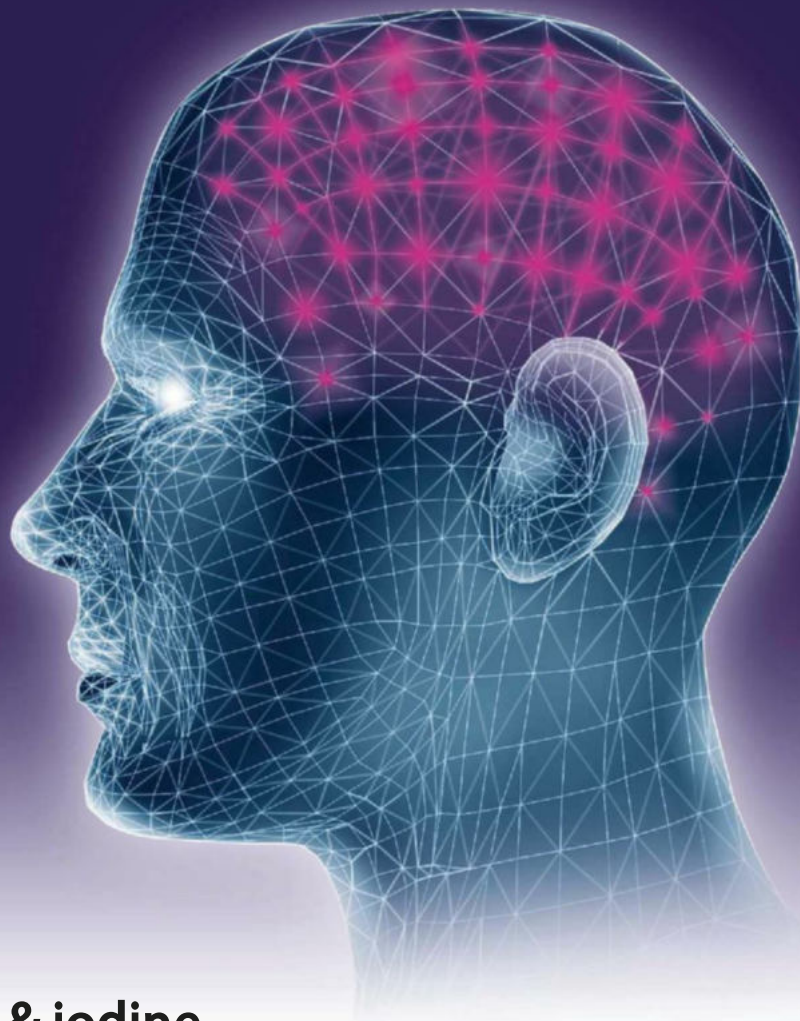
If you drink more water than your kidneys can remove (approximately one litre an hour), the concentration of sodium and other electrolytes in your blood begins to drop. Beyond a certain point, your cells will uncontrollably absorb water by osmosis and swell up. In the brain this increases the pressure against your skull, which leads to headache, confusion, vomiting and (ironically) thirst. If it isn't treated promptly, this progresses to seizures, brain damage and death. **LV**

NEXT ISSUE:

Why is there poo on the Moon?
Why do dogs bury bones?
Why are there two sexes?


Email your questions to questions@sciencefocus.com or post to BBC Focus Q&A, 2nd Floor, Tower House, Fairfax Street, Bristol BS1 3BN.

Feed your mind

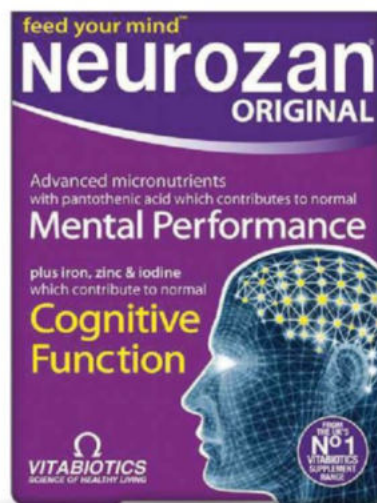


Micronutrients with iron, zinc & iodine,
which contribute to normal **cognitive function**

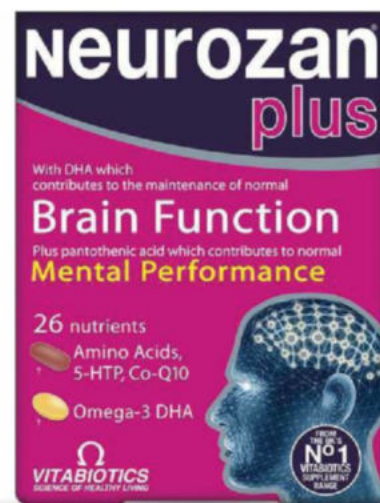
Neurozan® is an advanced, comprehensive formula to help safeguard your daily intake of essential vitamins and minerals. Including iron, zinc and iodine which support normal **cognitive function** and pantothenic acid which supports normal **mental performance**.

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ORIGINAL



DUAL PACK WITH DHA

Neurozan® tablets

From  Waitrose,
Holland & Barrett, supermarkets,
chemists, health stores & www.neurozan.com

†A beneficial effect is obtained with a daily intake of 250mg DHA.

*Nielsen GB ScanTrack Total Coverage Value Sales 52 w/e 25th April 2015.




**Britain's No.1
supplements***




VITABIOTICS
SCIENCE OF HEALTHY LIVING

HELEN CZERSKI... **BAKING SCIENCE****“CAKES AND BISCUITS BOTH GO STALE, BUT WHAT MAKES ONE GO HARD AND THE OTHER GO SOFT?”****T**

he biscuit tin in my office is an essential tool for getting science done. For pondering the thorniest scientific problems, tea alone is not enough and a chocolate biscuit or two is necessary to help the process along. But last week I didn't put the

lid back properly and by Monday morning my stash of biscuits was soft and spongy. Their weedy nature certainly didn't hit the biscuit spot. At the same time, leftover cake in my kitchen at home was getting closer and closer to the texture of a dry loofah, hard and rigid. Both cake and biscuits were going stale, but what makes one go hard and the other go soft? This distinction played a role in the famous tax decision on Jaffa Cakes in 1991, because the court had to decide whether to classify them as cakes or biscuits. It was decided that they are cakes, but it turns out that the innards of cakes are a bit more mobile than most people suspect.

I like to think of both cakes and biscuits as food architecture – a structure made of different interlocking components. Baking is a process of construction, and the texture of cakes and biscuits reflects their structural integrity. The framework of the cake is provided by the flour. Flour is about 75 per cent starch, and it's the starch that provides the strength. Working with the starch is gluten, an elastic protein that forms a network holding everything together with enough stretchiness to let the dough rise. Sugar, fat and eggs mostly help make and hold bubbles of gas that expand in the oven. So when it comes to whether the cake is hard or soft, the place to look is the major structural support: the starch.

When I bake a cake, the time in the oven is a part of the building process. The heat forces the starch granules in the mixture to absorb water and expand. Water can slip into the gaps between the huge molecules that make up the starch grains, pushing them apart. The final baked cake is soft, because the starch arrangement is soft. But the second you take it out of the oven, the process of going stale starts. It's got nothing to do with bacteria or mould. It's all about the position of the starch molecules.

Even as the fresh-baked smell is wafting across the kitchen, small rearrangements are happening inside the cake. Water molecules are small and mobile, and when they're parked between the starch molecules, the giant starch chains can shift. As time goes on, the starch



chains slowly shunt to line up, forming regular crystalline regions instead of messy amorphous ones. This is why the cake goes hard – its main structural component is getting more rigid. Sugar and fat slow this process, but they won't stop it. The cake drying out isn't the major player here.

Biscuits are different because they start off with much less water. Baking a biscuit dries it out pretty thoroughly, so the starch is immobile and the structure rigid. But sugar absorbs water from the air and will pass

it on to the starch, softening the structure. So biscuits go soft at first, although they will eventually go hard if the starch crystallises.

The details depend on the exact mixture of ingredients and the conditions in which you store your cakes or biscuits. The lesson here is clear – put the lid on the biscuit tin and eat your cake sooner rather than later! And that's the sort of thought that really cheers up a tea break... ☺

Dr Helen Czerski is a physicist and BBC science presenter whose most recent series was *Colour: The Spectrum Of Science*.

DISCOVER MORE

Did you miss *Colour: The Spectrum Of Science*? You can buy all three episodes of the series in the BBC Store at store.bbc.com

NEXT ISSUE: RAINDROPS ON WINDOWS



LIGHT SHOW

Even as late as the 17th Century, some people thought the brain was a flabby organ, incapable of thought. But as this artist's impression of a human brain shows, the organ is filled with a stunning array of neurons, each playing its vital part in helping the brain to regulate and control the mind and body.

PHOTO: GREG DUNN



HOW DO WE KNOW...

HOW THE BRAIN WORKS?

It's the most complex machine in the Universe, but we're slowly getting our heads around the organ between our ears

WORDS: CHRISTIAN JARRETT

R

ome, 2nd Century AD. An audience of philosophers and politicians has gathered to watch Galen of Pergamon, the 'prince of physicians', perform a public demonstration involving a pig. The animal's squealing falls suddenly silent as Galen severs its laryngeal nerve – the neural link connecting its voice box to its brain. The crowd audibly gasps with astonishment. Why were they so shocked? Galen had just proved that the brain, not the heart, controls behaviour.

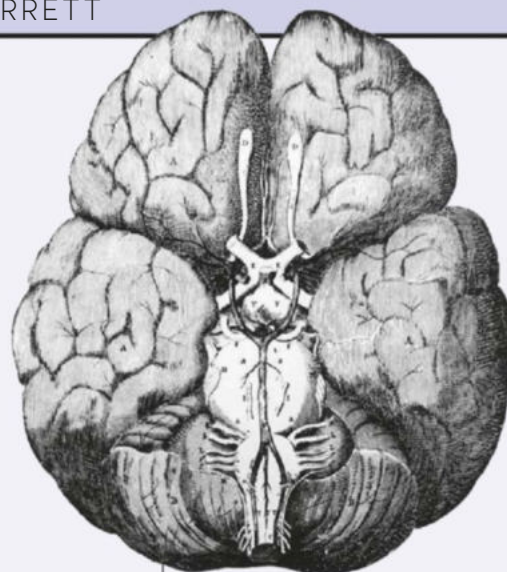
This might not sound groundbreaking to our modern ears, but the historian Charles Gross describes it as "one of the most famous single physiological demonstrations of all time". Although Galen

wasn't the first to recognise the functional importance of the brain, he was the first to carry out a public experiment supporting his case. In Galen's time, the 'cardiocentric view' – the idea that thought, mind and soul are located in the heart – remained dominant, and would do for centuries. You'll notice that its legacy lives on today, whenever we use sayings such as 'learn things by heart' or 'we've had a change of heart'.

The pig demonstration reflects in miniature the longer story of how we've come to understand the brain – it's a tale of colourful characters, ghoulish experiments, and stubborn myths.

CURDS AND SPIRITS

For much of history, our understanding of the brain was often more of a philosophical than a scientific pursuit. This is partly because, until the last century, the biological study of our grey matter was mostly dependent on post-mortem investigations of animal brains and bodies, and only more rarely – thanks to a long-running church ban – human



↑ Christopher Wren's highly detailed illustrations complemented Thomas Willis's writings about the brain's anatomy

brains. It's amazing to think that as late as 1652, the philosopher Henry More wrote that the brain had no more capacity for thought than "a cake of suet or a bowl of curds".

One of the most influential brain dissectors who helped overturn these beliefs was the English doctor Thomas Willis. He authored the magisterial book *Anatomy Of The Brain*, published in 1664, which featured illustrations by Christopher Wren. Willis made astute and visionary arguments that complex

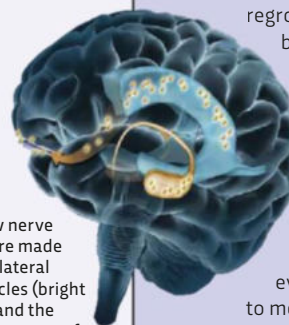
Scientist: Peter Eriksson *et al*

Date: 1998

Discovery: Adult humans can grow new neurons

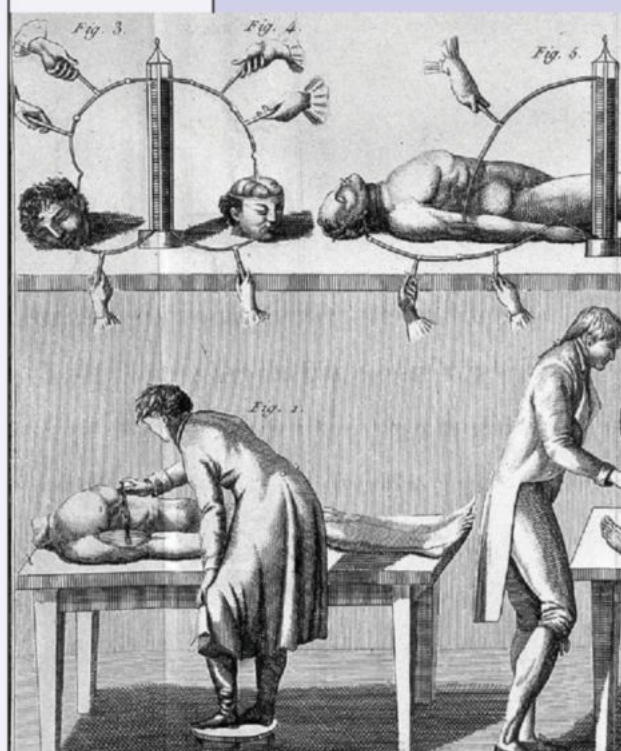
"Everything may die, nothing may be regenerated." In 1913, neuroscience pioneer Santiago Ramón y Cajal wrote these words about the prospects for regrowth in the adult human brain. For much of the last century, the evidence seemed to back this view – in fact, Cajal's "harsh decree", as he called it, became something of a dogma. But from the 1960s onwards, contrary evidence gradually began to mount, showing that adult rats, cats, birds and even monkeys can grow new neurons – a process known as neurogenesis. Despite this, for many more years the mainstream establishment refused to believe that this was true of humans.

Today, however, it is widely acknowledged that neurogenesis does take place in the brains of adult humans, specifically in the dentate gyrus region of the hippocampus and in the lateral ventricles. This discovery is thanks in part to research led by the neurologist Peter Eriksson, which involved cancer patients who'd been injected with a dye to monitor tumour growth. Whether we can exploit adult neurogenesis to develop medical treatments for brain injury and illness remains for now an urgent open question.



↑ New nerve cells are made in the lateral ventricles (bright blue) and the dentate gyrus of the hippocampus (light brown)

↓ Giovanni Aldini proved that electricity is integral to communication between nerves



● mental functions are carried out by the cerebral cortex. This part of the brain had long been seen as little more than a useless 'rind' – cortex means 'rind' or 'husk' in Latin.

The continuing lack of scientific knowledge about the brain allowed many mistaken theories to survive until relatively recent times – theories that seem absurd by modern standards. For example, another long-running belief (this one strongly endorsed by Galen) was that the brain pumps 'animal spirits' around the body.

Our leading physicians and scientists believed right up until the 18th Century that nerves were filled with these animal spirits – mysterious entities that the philosopher René Descartes described as "a very fine wind". The breakthrough that led to the animal spirits idea being overturned had to do with electricity, and specifically the emergence of 'electrotherapy' as a treatment for paralysis.

Public demonstrations again played their part in changing minds. In an event held in 1803 in London, for example, Giovanni Aldini (nephew of the pioneering anatomist Luigi Galvani) applied electricity to George Forster's brain to show how it caused the muscles of his face to twitch. Forster didn't know much about this – he'd just been hanged for the murder of his wife and child. But for the audience it helped to show how electricity was part of the way that nerves communicate.

However, even as the scientific establishment came to recognise the functional significance of the brain, and especially the cerebral cortex, another mistaken dogma persisted – the idea that mental functions, such as language, are

distributed uniformly throughout the cortex rather than being partly localised in specific regions.

One historical patient played a particularly important role in helping to overturn this idea. His name was Louis Victor Leborgne but he was nicknamed 'Tan' because this was virtually the only word he could utter. At autopsy, the French neurologist Paul Broca discovered that Leborgne had highly localised damage to a region in his left frontal cortex, known today as Broca's area, and he inferred that the damaged region must play an important role in speech.

Broca's presentation of Leborgne's case to the Société d'Anthropologie and the Société Anatomique in 1861 was instrumental in convincing the academic community that language function is particularly dependent on the frontal lobes. The historian Stanley Finger describes this moment as a "key turning point in the history of the brain sciences". Patients like Leborgne, with particular mental or physical deficits tied to specific areas of brain damage, have been one of the most important sources of information about the workings of the brain, and this is still true today.

NERVOUS SCIENCE

At the end of the 19th Century, brain science was focused once again on the perplexing issue of how exactly nerves manage to communicate with each other. While the earlier realisation of electricity's role had helped to debunk the notion of animal spirits, it was clear that there was more to nerve communication.

We know today that electrical current along a nerve cell ●

TIMELINE: BRAIN SCIENCE

Doctors and neuroscientists have been attempting to unravel the secrets of the brain for centuries, but this intriguing organ is proving a tough nut to crack

425 BC



425 BC

The Hippocratic treatise *On the Sacred Disease* states, contrary to the dominant cardiocentric view, that "from the brain and the brain only arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs, and tears".



GALEN OF PERGAMON (c.130-210)

In the 2nd Century, the philosopher performs the pig demonstration (see main text), showing that the brain controls behaviour.

1543

1543

Renaissance anatomist Andreas Vesalius publishes his landmark book *On The Fabric Of The Human Body* showing some of the most detailed dissections of the human brain ever produced.



1848

ALOIS ALZHEIMER (1864-1915)

In 1901, the German psychiatrist makes detailed notes on Auguste Deter, the first person diagnosed with Alzheimer's disease. "I have lost myself," she tells him.



1848

Railway worker Phineas Gage becomes one of the most famous patients in neuroscience after surviving an accident in which an iron rod passes straight through the front of his brain.

1830s

1830s

Phrenology reaches the peak of its popularity. This was the mistaken idea that psychological aptitudes and personality traits can be discerned from the bumps on someone's skull.



SANTIAGO RAMÓN Y CAJAL (1852-1934)

In 1913, the Spanish neuroscientist publishes *Degeneration And Regeneration Of The Nervous System*, detailing his groundbreaking findings on brain injury and recovery. However, he also claimed in error that new neurons do not grow in adult brains.

1953

Patient Henry Molaison undergoes brain surgery for intractable epilepsy. The procedure leaves him with profound amnesia and he becomes one of neuroscience's most studied individuals.



1953



OLIVER SACKS (1933-2015)

In 1985, British neurologist Oliver Sacks publishes his best-selling book *The Man Who Mistook His Wife For A Hat*. He becomes renowned for chronicling the human stories of brain illness and injury.

2013

President Barack Obama launches the BRAIN Initiative. "As humans, we can identify galaxies light-years away, we can study particles smaller than an atom," he says, "but we still haven't unlocked the mystery of the three pounds of matter that sits between our ears."



2013

● (neuron) causes it to release chemicals across a tiny gap – a synapse – and these chemicals, known as neurotransmitters, are then picked up on the other side by the receiving neuron. However, in the late 1800s, even the best microscopes and staining methods were incapable of revealing the presence of these gaps between neurons. This led the Italian scientist Camillo Golgi and his contemporaries to propose that nerves are fused together – an erroneous idea known as the ‘reticular theory’ (from the Latin for ‘net’).

It was the Spanish neuroscientist Santiago Ramón y Cajal who killed off the nerve net idea thanks to the advances he made in cell staining techniques, which made it clear that neurons are not joined together after all. Once again, however, old ideas died hard. In 1906, when Golgi and Cajal were jointly awarded the Nobel Prize for Physiology for their work on brain anatomy, Golgi used his winner’s speech to defend his reticular theory and brand Cajal’s ideas as little more than a fad.

In the 20th Century, technology began to play an increasingly important role in advancing our knowledge of the brain, particularly by allowing psychologists and neuroscientists to monitor brain activity. In the 1920s, scientists started to use electroencephalography (EEG), which involves recording electricity emitted by the brain through electrodes placed on the scalp. Previously, researchers had had to make assumptions about the location of different mental functions based on the effects of brain injury and by looking for patterns



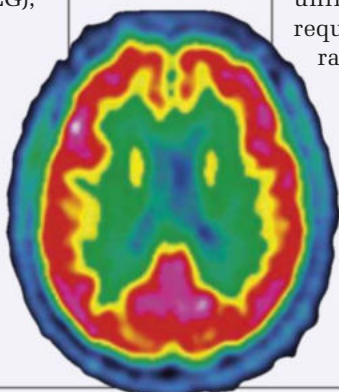
↑ Electroencephalograms (EEGs) have been used since the 1920s to record electricity produced by the brain

of damage at post-mortem. With EEG they could see how different regions of the brain become more active depending on what the person was saying, thinking or doing.

But the problem with EEG is that while it provides good temporal resolution – revealing changes in brain activity from one millisecond to the next – its spatial resolution is crude. This limitation was overcome in the 1960s with the advent of positron emission tomography (PET), which allowed researchers to monitor changing patterns of blood flow in the brain in high resolution. Things progressed even further in the 1990s with the emergence of functional magnetic resonance imaging (fMRI) – this method also has good spatial resolution, but unlike PET it does not require the injection of a radioactive isotope.

fMRI has had a huge influence on the study of the brain, and is now the principal technique used in the increasingly dominant field of cognitive neuroscience, merging psychological and biological approaches

↓ Positron emission tomography (PET) uses a radioactive tracer and a special camera to image organs in the body, including the brain



to brain function. These are the kinds of studies that lead to colourful images of ‘blobs on the brain’, where the blobs usually illustrate areas thought to contain heightened activity as the participant performs different tasks. In 2013, a review of the field estimated that over 130,000 fMRI research studies had been published, a figure that will by now be substantially higher.

BREAKTHROUGHS GALORE

Our increasingly sophisticated methods for recording and decoding brain activity have helped contribute to some of the most exciting and important breakthroughs in neuroscience in recent years. For example, there has been huge progress in brain-machine interfaces, which enable paralysed people to control computer cursors or prosthetic limbs using their thoughts alone. Other research has shown that it’s possible to use recorded brain activity patterns to communicate with some patients who were previously thought to be in a non-communicative, persistent vegetative state.

Recent times have also seen great leaps in our ability to

GLOSSARY

Cerebral cortex

The outer layer of the brain can be split in half lengthways, and each half is divided into four lobes: the frontal lobe, the temporal lobe, the parietal lobe, and the occipital lobe.



fMRI

Functional magnetic resonance imaging is used to detect areas of the brain that are working harder than others.



Neuron

One of the main cell types in the brain. An adult has about 85 billion neurons, forming over 100 trillion connections.



Synapse

The tiny gap between neurons. Chemical messengers are released by a neuron, travel across the synapse, and get absorbed by the receiving neuron.



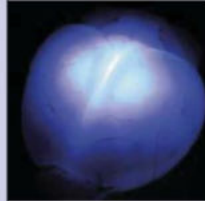
Ventricles

These fluid-filled cavities in the brain act as a kind of shock absorption system.

→ Transcranial magnetic stimulation can be used to treat depression, by stimulating the left frontal lobe



↓ This mouse brain is illuminated by a tiny LED implanted inside it for neuroscience research



manipulate brain activity. One technique that's increasingly useful is known as transcranial magnetic stimulation (TMS), which involves holding a magnetic coil over the head. This has the effect of temporarily disrupting brain function beneath the coil – an approach that can be used to provide a robust test of a brain region's presumed function. If a research participant cannot perform a given mental feat while a specific area of their brain is disabled, this strongly suggests that the affected brain area is necessary for the execution of that particular mental function.

At a more microscopic level is another exciting modern technique known as 'optogenetics'. It is used in animal research and involves injecting light-sensitive genes in individual neurons. Differently coloured lights can

then be used to switch these neurons on and off, enabling researchers to explore their specific function, for example in learning and memory. In 2016, this technique was used to reactivate networks of neurons in mice with a form of Alzheimer's disease, allowing them to remember things they had previously forgotten.

Although we've made great strides in our understanding of the brain, the truth is that we've barely scratched the surface. Sadly, devastating illnesses like Alzheimer's and motor neurone disease still remain incurable. Let's hope this will change as governments in the USA and Europe pour record levels of investment into ambitious new neuroscience research programmes.

One huge US project is known as the BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies) and its main emphasis is on finding new ways to observe brain function. In Europe we have the Human Brain Project funded to the tune of €1bn, with the aim of building a computer model of the human brain from the bottom up. A key player in this project is neuroscientist and entrepreneur Henry Markram, who in a TED talk said: "It is not impossible to build a human brain, and we can do it in 10 years." That was in 2009. In three years time, we'll find out if he was right... 🧠

Christian Jarrett is author of *Great Myths Of The Brain*. Follow him on Twitter @Psych_Writer.

Visit the BBC iWonder website to read a feature about whether technology can halt the dementia time bomb at [bit.ly/dementia_tech](https://www.bbc.com/iwonder/dementia_tech)

NEXT MONTH: UNDERSTAND GRAVITY

↓ Quadriplegic Jan Scheuermann uses thought to control a robotic arm



OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

MAY 2016

EDITED BY JAMES LLOYD



DISCOVER MORE



For more TV, radio and events listings, check out #BrainFood, published every Friday on our website bit.ly/BBCFocusBrainFood

01 FEAST OUR EYES ON FEATHERS

**FEATHERS:
DISPLAYS OF
BRILLIANT
PLUMAGE BY
ROBERT CLARK**
IS OUT NOW (£19.99,
CHRONICLE BOOKS).

With its extravagant plume of feathers, this flamingo wouldn't look out of place in the Bolshoi Ballet. Its rich pink coat – a result of the heavy preponderance of carotenoid pigments in its shrimp-and-algae diet – indicates to potential mates that this is a particularly healthy and well-fed specimen.

For more images of showstopping plumage, *Feathers* is the new book from award-winning photographer Robert Clark. Featuring more than 60 close-ups of feathers from around the world, there's also an explanation of each one's main function, whether that's attracting a mate, helping the bird to fly or just keeping it warm. It's natural selection at its most inventive.

One of the many striking images in Robert Clark's latest book, *Feathers*

Angela Rippon sets out to discover the truth about dementia in this new BBC documentary



02

BECOME MORE DEMENTIA AWARE

Today, there are over 850,000 people living with dementia in the UK, and that's set to rise to two million by the 2050s. Dementia Awareness Week, which takes place this year on 15-21 May, aims to raise awareness and understanding of this common, debilitating and often frightening illness.

Dementia is actually an umbrella term for a range of brain diseases, the most common of which is Alzheimer's disease. Symptoms of Alzheimer's include memory loss, confusion, and problems with speech and communication. As yet no cure exists, but the Alzheimer's Society estimates that even delaying the onset of dementia by five years would halve the number of deaths from this condition, saving 30,000 lives a year.

Six years ago, Angela Rippon lost her mother as a result of dementia. In *The Truth About Dementia*, she embarks on a personal and moving exploration of the illness, meeting the scientists who are at the forefront of the search for a cure. She finds out how 'exercising' our brains could help keep dementia at bay, and decides whether or not to take a genetic test that would reveal her own likelihood of developing the condition.

To find out how you can get involved with Dementia Awareness Week, visit alzheimers.org.uk/remembertheperson

WATCH THE TRUTH ABOUT DEMENTIA

ON BBC ONE, 19 MAY AT 9PM.

03 TALK ABOUT THE WEATHER

The weather is something of an obsession for us Brits. We love to talk about it, and we love to complain when the forecasters get it wrong. But our ability to predict the weather has come on in leaps and bounds since the 19th Century, when atmospheric physics was still a fledgling science.

In *The Men Who Made The Weather*, Alok Jha charts the history of weather forecasting, from its early days through to today's billion-dollar

industry. Over three episodes, he'll look at how it helped save lives at sea, its crucial role in military strategies, and its modern-day status as a cutting-edge, supercomputer-powered endeavour. It's a story that features an eccentric cast of characters and a lot of hard graft.

THE MEN WHO MADE THE WEATHER

IS ON BBC FOUR THIS MAY – CHECK [RADIOTIMES.COM](http://radiotimes.com) FOR FULL DETAILS.

The history of meteorology is explored in a new BBC Four series



04

MEET THE MAN WHO STUNG HIMSELF 83 TIMES



Dr Justin Schmidt is a man on a mission. Since the 1970s, this US entomologist has been cataloguing the severity of insect stings, mostly using himself as the test subject. Schmidt's Sting

Pain Index compares the relative agony of wasp, bee and ant stings using a numerical scale (1 for mild, 4 for excruciating). The complete index, which includes descriptions worthy of a wine connoisseur, is published for the first time in his new book *The Sting Of The Wild*.

We asked Schmidt to pick out his five most memorable stings...

1

BUMBLEBEE

Genus: *Bombus* spp.

Pain level: 2

Description: Colourful flames. Fireworks land on your arm.

"I was about five years old, playing in our backyard, when I discovered a bumblebee colony. They took umbrage – one bee stung me in the back of the neck five times!"



2

TARANTULA HAWK WASP

Genus: *Pepsis* spp.

Pain level: 4

Description: Blinding, fierce, shockingly electric. A running hairdryer has just been dropped into your bubble bath.

"I found a tree in Arizona covered with these wasps. One of them swooped down and got my finger – after that I just remember lying down and screaming."



5

BALD-FACED HORNET

Species: *Dolichovespula maculata*

Pain level: 2

Description: Rich, hearty, slightly crunchy. Similar to getting your hand mashed in a revolving door.

"Me and my school friends found a hornets' nest in an apple tree. I was the smallest, so to prove myself I threw a rock. It scored a direct hit; the hornets came roaring out."



3

FLORIDA HARVESTER ANT

Species: *Pogonomyrmex badius*

Pain level: 3

Description: Bold and unrelenting. Like somebody is using a power drill to excavate your ingrown toenail.

"I went out to collect these ants when I was a graduate student at Georgia. One of them hit me as I was digging – wow! It was a deep, throbbing pain, almost at bone level."



4

BULLET ANT

Species: *Paraponera clavata*

Pain level: 4

Description: Pure, intense, brilliant pain. Like walking over flaming charcoal with a three-inch nail embedded in your heel.

"The holy grail of stinging insects. When I was stung by one in Brazil, the waves of pain lasted for 12 hours."



PHOTOS: BBC, ISTOCK, GETTY X4, ALEX WILD

THE STING OF THE WILD
BY JUSTIN O SCHMIDT

IS PUBLISHED ON 31 MAY (£16, JOHNS HOPKINS UNIVERSITY PRESS).

05

EXPLORE OUR INNER ANIMAL

Comedian SARA PASCOE has been thinking about the essence and origins of female sexuality. She talks to HELEN PILCHER about her new book, *Animal*

Why did you decide to write this book?

I've been interested in the subject for a long time. I'd noticed that where feminist articles often blame magazines and popular culture for the way women feel and are treated, the scientific literature tends to focus more on biology and evolutionary theory. I wanted to write a book that combines both these angles, alongside my own personal experiences.

There's a lot of great science in the book. Where does your passion for science come from?

A big part is from my mum. She's amazing. She did a PhD in the genetics of autoimmune disorders while raising three children as a single parent. She was so excited about how experiments could be applied to help change people's lives, and I think some of that rubbed off on me.

How animal are we?

We're all part animal, part conscious. Writing *Animal* has made me realise how much of our behaviour is underpinned by millions of years of evolution. It can explain everything

Sara Pascoe's new book looks at how different factors from biology to the mass media have influenced our perception of female sexuality

from mating preferences to jealousy and infidelity. But we're more than that. We have these big, crinkly, clever brains that enable us to consider whether or not we should act on these animal impulses. When a dog humps someone's leg, it's not worrying about whether or not the leg fancies it back, or if the leg is married or underage. The dog is just acting on impulse. We, on the other hand, have the capacity to understand that actions and desires are different things. That makes us unique.

In your book, you say that our ideas of sexuality are often male-biased. Why do you think this is?

The scientists who discovered evolution were Victorian men. At the time, women were oppressed and dismissed as coy, chattering nurturers. The view was that women got their pleasure not from having sex, but from having babies. It's led to a model of human sexual behaviour that completely ignores female lust and pleasure as forces. So for example, if a woman sleeps with a co-worker, often it's interpreted as an act of manipulation – her wanting to sleep her way to the top – rather than that she just plain fancied the guy. There's this whole agenda going on.

What was the most surprising thing you learned?

How much 'falling in love' is influenced by brain chemistry. MRI scans show how love causes the brain to flood with dopamine. The release men get from orgasm is the same as a heroin user gets from a hit. It's addictive.

We have all of these songs and poems and conversations about love, but to see it happening in the brain in black and white is just huge. It doesn't undermine love or take away any of the feelings or the magic. It just makes it even more incredible.

While exploring the neurochemistry of love, you underwent an MRI scan. How was that?

Exciting! You lie there and you're told to stay completely still and there's all this clanging. I was like a child who wanted to impress their teacher – it's the stillest I've ever been.

This is a very personal, emotive book. It made me laugh but it also made me cry. What do you hope to achieve from it?

I want people to accept themselves and be forgiving of what they find. I want them to be interested and curious.

A third of the book is about consent. There was a case in the US where a football player was found guilty of raping an unconscious woman, yet to this day he claims he did nothing wrong. I want to promote discussion. If we can educate people to better understand the issues surrounding consent, then this becomes a solvable crime. Our legal system is not set up to try rape and sexual assault effectively. That needs to change.

Has writing your book been cathartic?

Yes, it really has. Sometimes, writing things down really helps you to work out what you think. I was able to look back at some of the more difficult parts of my life and put a full stop after them. It's also made me realise how well my Mum has shaped me as a person. It's almost like I've been able to write her a love letter... in a book.

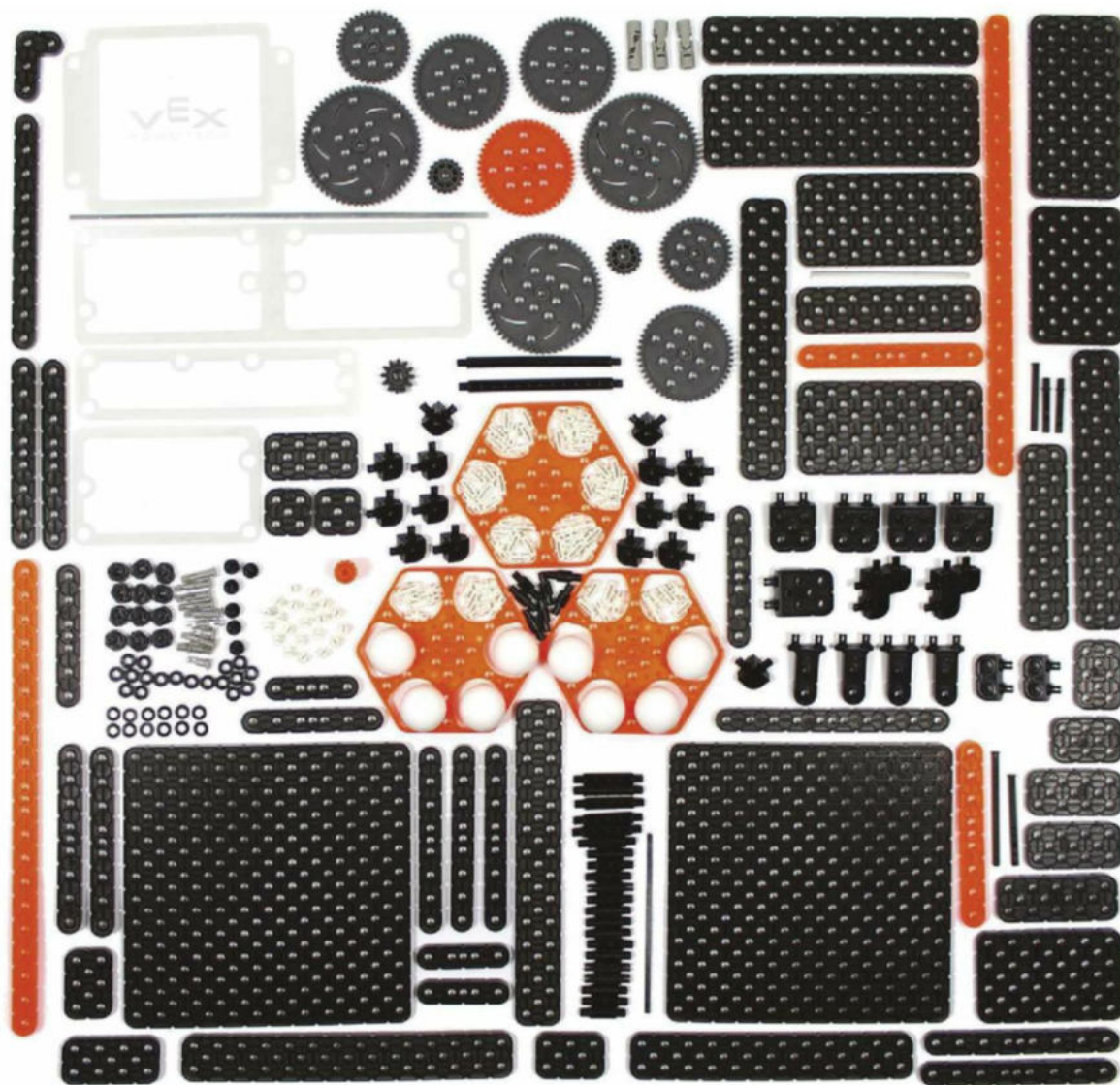
"MRI scans show how love causes the brain to flood with dopamine. The release men get from orgasm is the same as a heroin user gets from a hit. It's addictive"

PHOTOS: ©DAVE BROWN

ANIMAL: THE AUTOBIOGRAPHY OF A FEMALE BODY BY SARA PASCOE

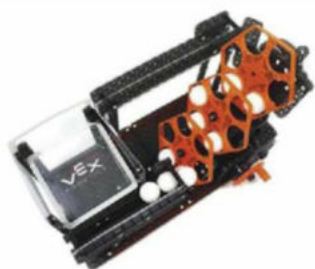
IS OUT NOW (£12.99, FABER & FABER).

06 BUILD OUR OWN ROBOT



Ever since our childhood days playing with Lego and Mouse Trap, we at *BBC Focus* have always loved building our own contraptions. So we were pretty chuffed to receive a new construction kit from HEXBUG in the post.

Assembled from over 260 pieces, the 'Hexcalator' ball machine is a device worthy of Heath Robinson. Turning the knob rotates the three hexagonal wheels, lifting the balls up onto the ramp so that they can roll down ready to be lifted again. And if turning a crank is just too much effort, a motor kit can also be



purchased separately.

The Hexcalator is part of HEXBUG's VEX Robotics range, designed to give budding engineers and roboticists hands-on experience with the basic principles of

mechanics. These micro-robots were originally designed for the classroom, and there are now VEX Robotics student competitions all over the world. Other machines in the new range include a robotic arm (winner of the Toy Industry Association's Educational Toy of the Year award), a mechanical crossbow, a catapult and some funky racing cars. So what're you waiting for? It's time to get building!

HEXBUG's robotic building kits have found their way out of the classroom

DON'T MISS

THE SKY AT NIGHT

On the eve of Mercury's transit across the Sun, this month's episode takes an in-depth look at the smallest planet in our Solar System. How did it form, why is it shrinking, and what's the best way to view the transit? Watch it on BBC Four, 8 May at 10pm.

PROF MATTHEW COBB SHARES HIS FAVOURITE SPOTS IN MANCHESTER



1 CASTLEFIELD CANAL BASIN

Historic area teeming with trendy bars.

2 MUSEUM OF SCIENCE AND INDUSTRY

This museum features displays of aircraft, trains and industrial machines.
Liverpool Road, M3 4FP
msimanchester.org.uk

3 MANCHESTER ART GALLERY

Home to an impressive art collection, including world-famous Pre-Raphaelites.
Mosley Street, M2 3JL
manchesterartgallery.org

4 THE RIVER MEDLOCK

This waterway has been cleaned up and is a lovely place for a stroll.

5 MANCHESTER MUSEUM

The University of Manchester's museum, with collections on everything from archery to Ancient Egypt.
Oxford Road, M13 9PL
museum.manchester.ac.uk

6 EPICERIE LUDO

Grocer and wine merchant, selling tasty pastries.
46 Beech Road,
Chorlton, M21 9EG
epicerieludo.co.uk

Manchester is a city of contrasts – world-renowned industrial heritage nestled beside 21st-Century developments, and surrounded by some of the most gorgeous countryside in the UK. Yes, it rains – but that's why it's so green! I love wandering around the **CASTLEFIELD CANAL BASIN** 1 an area that now combines bars with hundreds of years of history – Roman remains, the Bridgewater Canal (1761) and three railway lines (one now a tramway). It's a stone's throw from the **MUSEUM OF SCIENCE AND INDUSTRY (MOSI)** 2, the site of the world's first passenger railway station. Here, the past is so thick you can feel it in the air.

I love to visit the **MANCHESTER ART GALLERY** 3, which has one of the best collections of Pre-Raphaelite paintings. Sometimes incredibly powerful, sometimes cloying, my opinion of these artworks changes continually.

THE RIVER MEDLOCK 4, which snakes through the city, is a lovely place for a stroll. Some of the river is underground, as it used to collect effluent from the factories in east Manchester. Now the

factories are gone, the river is no longer polluted and is clean and clear. Surely some developer will set up Medlock Beach, as climate change brings the Med to Manchester!

One of my other favourite sites is the university's museum, **MANCHESTER MUSEUM** 5, as it has a fantastic collection of objects – exquisite fossils from the Cambrian Explosion and brilliant jewel beetles. It's close to Coupland Street, which is where Alan Turing worked in the last years of his life, where Peter Mark Roget (of the thesaurus fame) had a house, and where Ernest Rutherford, Hans Geiger and Ernest Marsden showed that atoms have internal structure in 1909.

For a bite to eat, I love **EPICERIE LUDO** 6 in the suburb of Chorlton. I lived in Paris for 18 years, and this small shop makes the best croissants this side of the Channel. About a 40-minute drive from the city centre is Jodrell Bank, now home to the Square Kilometre Array project. The beautiful Lovell Telescope, an engineering marvel from the 1950s, can be seen for miles around. I always wonder what the telescope is listening to... 7

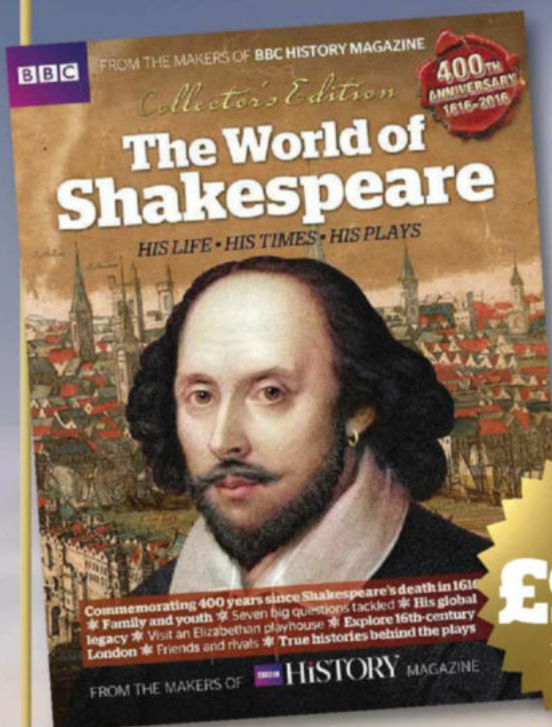
Matthew Cobb is a professor of zoology at the University of Manchester and author of *Life's Greatest Secret: The Race To Crack The Genetic Code*.



FROM THE MAKERS OF **BBC** **HiSTORY**
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- ◆ Meet his friends, family, colleagues and rivals
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- ◆ Explore his generation's world view and how it influenced his creative vision

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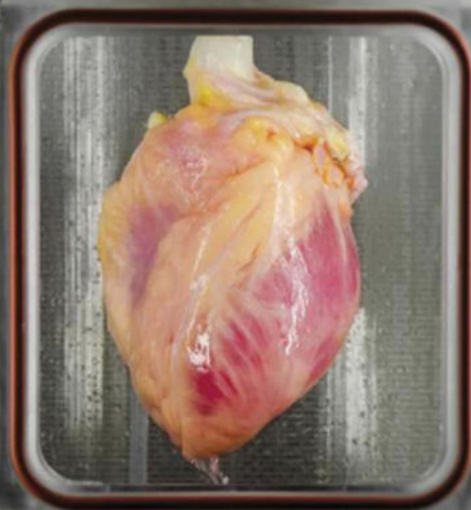


What was the poet and playwright's legacy to the world?

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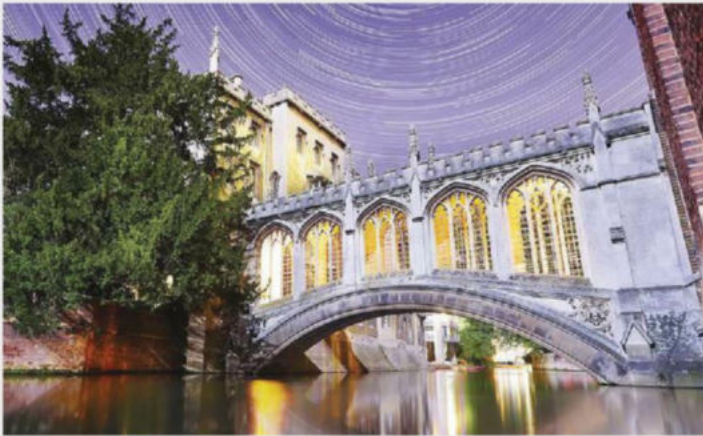
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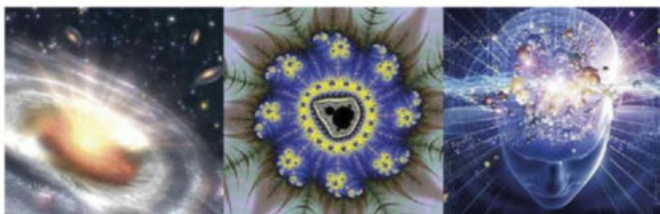
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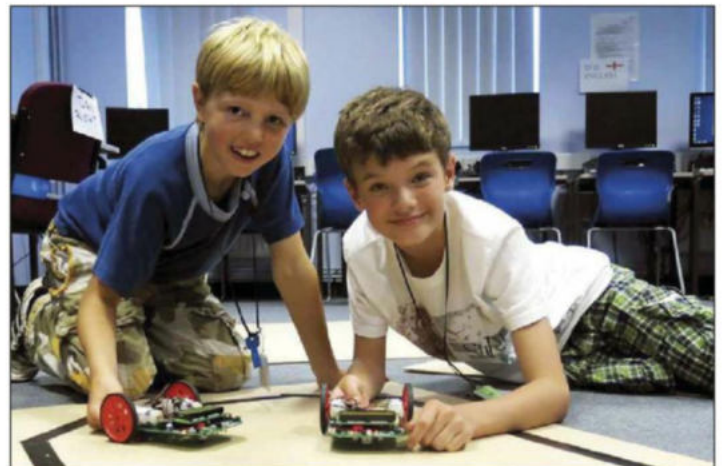
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“In the 1950s, the assumption was that girls would get married and not have jobs”

Dame Jocelyn Bell Burnell talks to **Helen Pilcher** about science, sexism and making the discovery of a lifetime

I grew up in Co Armagh, N Ireland. My father was an architect who did his own surveying. Sometimes, he'd let me come along while he took measurements. Then in the car on the way home, he'd let me reduce the observations. It introduced me to science and taught me how to design a good experiment.

In the 1950s, the assumption was that girls would get married and not have jobs. So at secondary school, girls did domestic science and boys did science. My parents had to fight to get me into science class. That first term we did physics and astronomy, and I discovered I was good at physics.

I did a physics degree at Glasgow University, where I was the only woman in my honours class. When I walked into the lecture theatre, everybody would wolf whistle at me. When I told my female housemates I was the only girl, they presumed I would change subject, but it never occurred to me.

To become an optical astronomer I would have to stay up at night, which I'm not good at. So I took an interest in radio astronomy, which you can do during the day.

I didn't think I was bright enough to go to Cambridge. When I was accepted to do a PhD there I was delighted. I spent the first two years – armed with screwdriver, wire cutters and pliers – helping to physically build the radio telescope.

When it was up and running; the telescope generated miles of data. It was my job to analyse it all. A small, quarter-inch smudge caught my eye. After many careful checks, I realised it was a signal from an entirely new type of stellar object.

When we described this 'pulsar' to the media, journalists would ask my supervisor about the science, but ask me about my vital statistics. It made me feel like a bit of meat.

I was enormously pleased when, in 1974, the Nobel Prize for Physics was awarded for the discovery of pulsars. It was the first time ever the prize had been awarded to astronomers, but my exclusion from it led some people to call it the 'No-Bell' Prize.



Since then, I have had a rich and varied astronomical career. The lack of a Nobel Prize has been more than compensated for by the many other rewards I've been lucky enough to receive. I think things are definitely improving for women in science, but there's still a lot more work that needs to be done.

Dame Jocelyn Bell Burnell is president of the Royal Society of Edinburgh and the discoverer of pulsars.

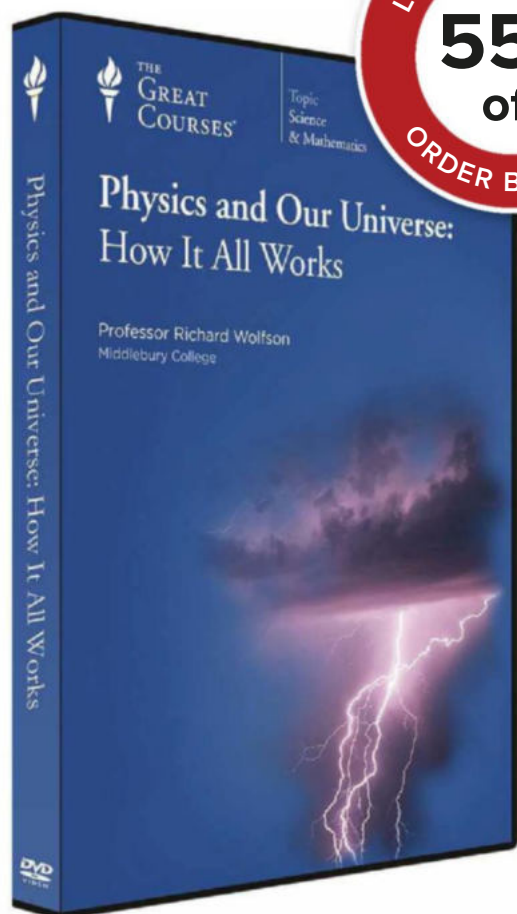
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NEXT ISSUE: PETER WHORWELL

I'm no longer an active researcher, but I do keep busy. I'm visiting professor at Oxford University and president of the Royal Society of Edinburgh. I like classical music and I'm incredibly fond of my garden. I'm also very active in the Quakers. It's an essential part of me. 🧘



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